Santa Barbara County Renewable Energy Blueprint

Economic Analysis

Prepared for the Community Environmental Council by University of California, Berkeley affiliates:

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Table of Acronyms

BAU	Business As Usual
CAISO	California Independent System Operator
CAFÉ	Corporate Average Fuel Efficiency
CCS	Carbon Capture and Sequestering
CCA	Community Choice Aggregation
CEC	California Energy Commission
CEC	Community Environmental Council
CCHP	Combined Cooling, Heat and Power
CFL	Compact Fluorescent Light
CHP	Combined Heat and Power
CT	Conversion Technology
CTL	Coal to Liquid
CSP	Concentrated Solar Power
DG	Demand Response
DNP	Domestic National Product
DOE	Department of Energy
DSM	Demand Side Management
EV	Electric Vehicle
GHG	Green House Gas
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation
HVDC	High Voltage DC
IPCC	International Panel on Climate Change
LED	Light Emitting Diode
MPR	Market Price Referent
MSW	Municipal Solid Waste
NG	Natural Gas
NGCC	Natural Gas Combined Cycle
NREL	National Renewable Energy Laboratory
O&M	Operations and Maintenance
PCT	Programmable Communicating Thermostats
PHEV	Plug in Hybrid Electric Vehicle
PV	Photovoltaic
SBC	Santa Barbara County
STE	Solar Thermal Electric

County	Residential , GWh	Nonresidential, GWh	Total, GWh/y	Population (thousand)	Per capita use kWh/y
Santa Barbara	807.00	2,407.00	3,214.00	400.00	8035
San Luis Obispo	646.00	938.00	1,584.00	255.00	6212
Ventura	1,787.00	3,789.00	5,577.00	796.00	7006
Total	3,240.00	7,134.00	10,375.00	1,451.00	7150
Total State	86,352.00	186,113.00	272,464.00	36,100.00	7547
USA	1,500,350.00	2,554,650.00	4,055,000.00	296,400.00	13681

Table 1, Electrical Energy Consumption on the Central Coast[1]

BAU	2005	2010	2020	2030
Electricity	2.70	2.82	2.82	3.33
Natural gas	4.55	4.55	5.42	7.00
Transportation fuels	8.22	8.29	9.70	11.18
Total	15.46	15.66	17.94	21.51

Table 2, Present and Projected Energy Consumption for Santa Barbara County[2]

Santa Barbara electricity is supplied by two utilities and is supplied by the following energy conversion technologies.

	PG&E[3]	SCE[4]	Average
Biomass and waste	5%	2%	3.5%
Geothermal	2%	9%	5.5%
Small hydro	4%	1%	2.5%
Solar	1%	1%	1.0%
Wind	1%	3%	2.0%
Coal	1%	8%	4.5%
Large hydro	20%	5%	12.5%
Natural gas	42%	54%	48.0%
Nuclear	24%	17%	20.5%
			100%

Table 3 Santa Barbara electricity, supplied by two utilities, showing portions of energy production by each energy conversion technology.

This composition deviates slightly from that of the entire state as indicated in Chapter 1, the “blue print”:

Sidebar: California’s Energy Mix. *California’s electricity is generated from the following sources:*

Total electrical potential: 36,000 MW	
Natural gas	*37.7 %*
Coal	*20.1 %*
Large hydro	*17.0 %*
Nuclear	*14.5 %*
Non-hydro renewables	*10.7 %*

From the master spreadsheet:[2]
In 2005 (see Fig. 1), Santa Barbara County used about 184 million gallons of gasoline, 27.7 million gallons of diesel,[5] 8.8 million gallons of jet fuel, 525,000 gallons of aviation gasoline, 155 million therms of natural gas, and 2,700 gigawatt hours (GWh) of electricity.[6] When we combine all of these energy sources and convert them to GWh, or terawatt hours (TWh) as a common unit of energy, we find that Santa Barbara County used about 15,500 GWh of total energy in 2005. We project, in a business-as-usual scenario, that this energy demand will rise to almost 21,000 GWh by 2020.

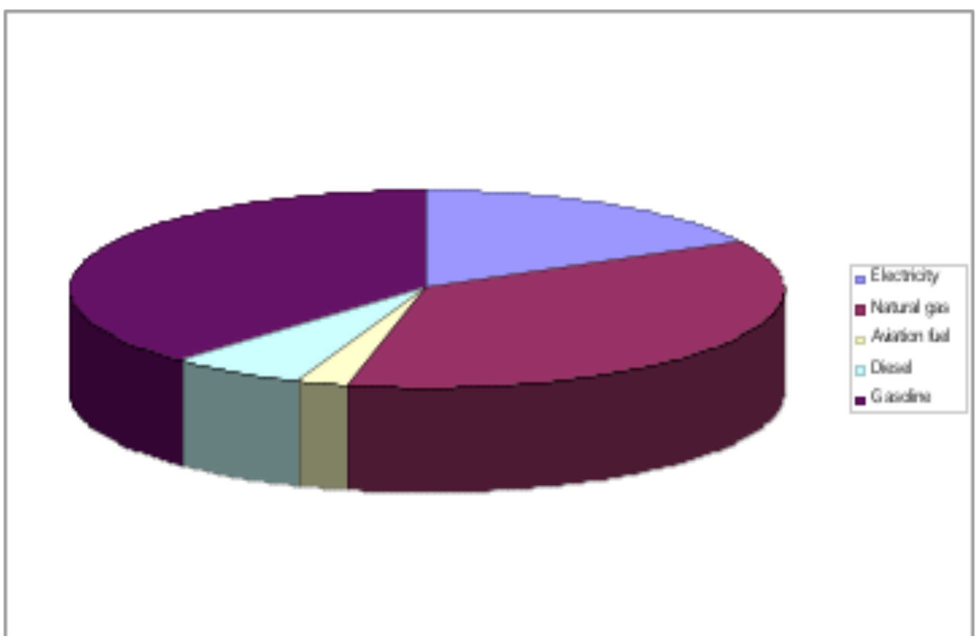


Figure 1 Santa Barbara County energy use in 2005. Derived from California Energy Commission, Santa Barbara Air Pollution Control District, and Department of Transportation figures.

I. Executive Summary

Santa Barbara County will financially benefit from becoming carbon neutral, our model indicating a net annual energy savings of more than $1.15 billion, or close to $2,300 per person per year. Our calculations include only costs to consumers. The fact that renewable energy requires more money to be spent in building infrastructure locally, and less to be spent on imported fossil fuels increases the financial advantage of renewable energy.[7]

Additionally, becoming carbon neutral will provide a template for other counties on how to mitigate climate change and financially benefit in the process. Our model, an active Excel spreadsheet, balances energy needs with projected future development of renewable energy (primarily wind power), which represent a small portion of the area's renewable energy potential. The final energy costs reflect the energy balance, energy cost projections, and estimates for the cost of energy conservation measures. The measures do not include conservation or any significant change of lifestyle. Vehicle fuel use is calculated with input from a modified VISION spreadsheet and is decreased considerably through increased vehicle efficiency and displacement by (largely) electricity. Efficiency in the building sector is projected to increase by 30%. The final scenario is not financially optimized. We have entered values that are conservative, and set goals that we found realistic and achievable. Additionally, for the sake of diversity, the model includes a variety of energy production and energy consumption technologies, rather than focusing on those that are the most efficient, or financially advantageous.

Santa Barbara County has sufficient wind power potential (mostly off shore) to supply close to 300 times its present electrical needs. Development of a small portion of this potential will displace fossil fuel use in the electricity sector as well as a considerable amount of fuel use. Wind power is an established technology that is competitive in price with conventional generation technologies. Recent increases in the cost of wind power, and in particular off shore wind power, have resulted largely from an inability for industry to meet demand. Prices should drop considerably again when the market equilibrates. The variability of wind presents a challenge for the grid to consistently meet load. This can be accomplished through a combination of diversifying the renewable energy sources (both with different technologies and different geographic placement), development of energy storage facilities, and through consumer adaptation to the changing supply (demand response).

With VISION, using vehicle retirement rates, we build the 2030 vehicle fleet by projecting sales rates of alternative vehicles and the evolution of CAFÉ standards. Electricity displaces about 8 times its energy equivalent in petroleum, resulting in a 10-fold energy cost decrease for electrical substitution in the

transportation sector. We project modest price increases for conventional fuel sources. Increasing the cost of fossil fuels will increase the calculated savings. Our use of VISION slightly underestimates the displacement of ICE, resulting in a 1.5% underestimation of total savings.

Much energy and money can be saved in the building sector by implementing increased efficiency measures, distributed solar power, solar thermal, and combined cooling heat and power. We project a 30% reduction in electricity and natural gas from Business As Usual (BAU) in the building sector by 2030, corresponding to 1.36% efficiency increase per year. We assign the cost of conserved energy to be 4.35 cents/kWh for electricity and 54 cents/Therm for natural gas. These are both conservative estimates, corresponding to conservation measures resulting only from utility incentives, and are more costly than voluntary change, increased standards, and Energy Star. It is very likely that energy conservation measures will achieve dramatically better reductions in building energy use, and will cost considerably less than estimated in our model.

It is important to note that all the studies consulted indicate that, while the necessary changes to become carbon neutral can be implemented without detriment (and possibly to great benefit), these changes will not happen naturally through market forces. Aggressive government and social programs will be required to overcome resistance to change. We present the following recommendations:

1) Aggressive coordinated public education effort drawing on local volunteers.
2) Establishment of a Santa Barbara Community Choice Aggregate to purchase and distribute electrical power.
3) Aggressive development of renewable electricity generation, wind power in particular. Wave Energy Conversion (WEC), and Municipal Solid Waste Conversion Technology (MSW CT) are also options.
4) Development of the infrastructure, such as Programmable Communicating Thermostats (PCT) to enable real time pricing of electricity.
5) Development of infrastructure necessary to publicly charge electric vehicles, and possibly draw energy from parked vehicles during peak electrical need.
6) Mandate a minimum tariff equal to the real time cost of marginal electrical energy production to be paid to any entity supplying electricity to the grid. This will encourage roof top solar power in particular and distributed generation (DG) and combined cooling heat and power (CCHP) in general.
7) Implementation of standard DG grid connections.

8) Study future potential consumer difficulties in technology adaptation, and make every effort alleviate problems before they happen.[8]

9) Accelerate adoption of increased efficiency technologies such as LED lights through education and subsidies.

10) Accelerate high efficiency vehicle penetration through subsidies, and early retirement buy back programs.[9]

11) Enforce improvements in building efficiency during building, time of sale, and renovations consistent with Title 24[10] and the "2030 zero energy challenge".[11]

II. Review of the costs of climate change/peak oil/air pollution/national security on our nation:

Santa Barbara County will financially benefit from becoming carbon neutral, our model indicating a net annual energy savings of more than $800 million, or close to $2000 per person Continued reliance on fossil fuels results in three distinct negative economic consequences: global climate change, Peak Oil, and external costs of conventional fuel use. This section gives a summary of each of these three economic consequences, and ends with a summary of the positive economic results of replacing fossil fuel energy with renewable energy.

Climate Change

The 2007, 4th International Panel on Climate Change (IPCC) report on climate change indicates that in the past century global temperatures have risen about 0.5 °C, and there has been about 17 cm of sea level rise. If we stabilize GHG levels we can expect another 0.5 °C rise in global temperatures and small increases in sea level in the next century, while models assuming future economic growth based on fossil fuels predict further temperature increases of about 4 °C and sea level rises of at least 26 cm. Calculation does not consider loss of Greenland ice sheet, which could result in 7 m of sea level rise. Already, subsequent studies indicate negative environmental impacts much worse than predicted by the IPCC.[12]

The "Blueprint", or Chapter 1 of the Community Environmental Council's report series, describes some of the important social impacts of climate change such as heat related deaths. Below, we summarize what is known about the economic consequences.

The October 30, 2006 Stern Review of Economics of Climate Change assessed a wide range of evidence on the impacts of climate change and on the economic costs. A number of different methods were used to assess costs and risks, resulting in a simple conclusion: "The benefits of strong and early action far outweigh the economic costs of not acting." While economic models predicted that the costs necessary to prevent further detrimental climate change would have an economic impact of less than a 1% loss in DNP, the cost of not acting was projected to be between 5% and 20% (or more) loss in DNP. The strong advice of the report is that significant changes in our GHG emissions (and thus in our economy) must happen in the next 10 – 20 years to prevent permanent environmental and economic damage.

The report went on to say that the costs of stabilizing the climate are significant, but manageable, and that delay would be much more dangerous. It called on an organized, international effort of all countries, which would not preclude economic prosperity. The report recommended:

1) **Emissions trading** with strong targets
2) International **technology cooperation** that included a doubling of funding for energy research and a five fold increase in funding for low carbon technologies.
3) Immediate international effort to **stop deforestation**
4) International efforts to **help poorer countries adapt** to the already unavoidable impacts of climate change.

Economic Impact of Peak Oil

The Hirsh Report[13] clearly outlines the danger of peak oil, and in particular the peril of delaying a shift to alternative energy sources. While oil production has peaked in several countries, national production curves often show an asymmetric sharp decrease after the peak date (see Fig. 2). Estimates for the peak date of world oil vary between now and a decade from now. Thus it is reasonable to expect a sharp drop in supply immediately after the unforeseeable passing of peak oil. As energy demand will continue to rise after peak oil, economic repercussions could be severe. A shift from petroleum energy sources is inevitable. While the consequence of shifting "too early" will result in slightly less than optimal economic prosperity, the consequence of shifting too late will likely result in catastrophic economic impact.

At the very least, higher oil prices will lead to exploitation of recovery and synthesis techniques that are more expensive, more harmful to the environment, and more carbon intense.[14] These techniques include enhanced oil recovery, and production of fuel from tar sands, oil shale, and coal. This transition will have a negative impact not only on the economy, but also on the local environment, global climate, and public health.

Transition to more expensive forms of petroleum extraction and synthesis may soften the economic impact of post peak oil, at the cost of degraded environment and health. For instance, synthetic chemistry can be used to turn coal into liquid hydrocarbon fuel (CTL), at slightly less than $40/barrel. While this price is considerably more than the $2/barrel to recover oil in Saudi Arabia, or even the $16/barrel using steam injection methods,[15] it is less expensive than the present $60/barrel price of oil on the world market. Thus the transfer to synthetic oil may not substantially increase the price of transportation fuels. The abundant world supply of coal could delay the crash associated with the end of peak oil. However, the use of CTL fuel has twice the associated CO_2 emissions as conventionally acquired gasoline,[11] and uses 10 gallons of water for every gallon of petroleum synthesized.[16] Lastly, the supply of coal is also not infinite and the coal remaining in the ground is of lower quality and more difficult to extract than previously. Recent studies indicate that peak coal is most likely sooner than first anticipated, and is projected as early as 2025.[17]

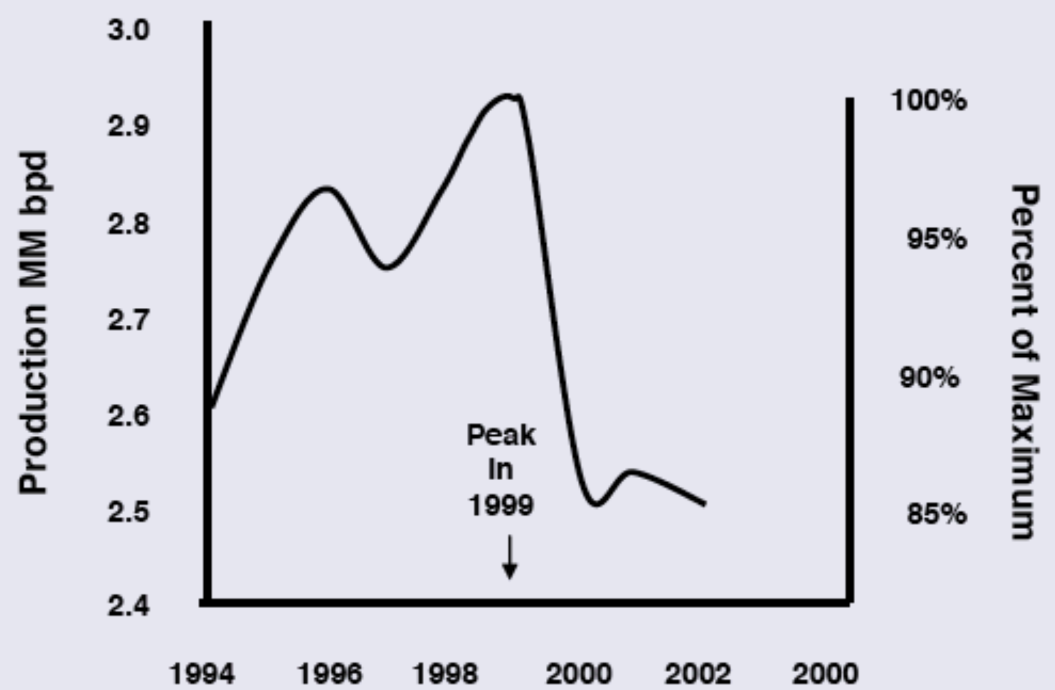


Figure 3. Oil production in the United Kingdom peaked in 1999 on very short notice. After the peak, the decline in production was very rapid.

Figure 2, From the Hirsh Report,[10] Oil production in the United Kingdom peaked in 1999 on very short notice. After the peak, the decline in production was very rapid.

Hidden Costs of Fossil Fuel Use: Externalities

Energy is often delivered to a consumer at far less than the total cost to society.[18] These "external costs" (Fig. 3) not born by the energy provider, are one of many forces that prevent the free market from serving society. Such externalities include government subsidies, hedging fossil fuel price volatility, loss of environment, dependence on foreign governments and related health costs. In order for a resource to be appropriate allocated for societal benefit, the full cost to society must be paid by *each individual decision maker* when a choice is made to consume energy (or any other commodity).[19] Otherwise the resource will be misallocated and society will suffer.

Subsidies

Government can make both direct and indirect subsidies available to an energy technology. Direct subsidies include direct payment and tax credits to the company or the consumer as well as manipulation of excise taxes. Indirect

subsidies include low interest loans, insurance (such as insurance provided to the nuclear power industry) infrastructure (such as the rail system that transports coal), the funding of related basic research, and protection of assets, both domestically and abroad. For instance, the argument has been made that US petroleum energy security benefited from the taxpayers' military investment in the Persian Gulf. This average annual external cost of 100 billion dollars would increase the price of gasoline about $1/gallon if it was internalized.

A recent review found that fossil fuels receive the majority of federal subsidies, followed by nuclear power.[20] This hides the true cost of these technologies, and results in increased use of these technologies. Analysis by the U.S. energy Information Administration found that from 1% to over 7% of total U.S. carbon emissions could be attributed to the structure of the subsidies provided to the energy industry.[15]

Loss of the environment

The services that the environment provides are worth money to the public. These services may be ecosystem services such as a natural source of clean water, or recreational facilities for the public. If these services are destroyed through the extraction of natural resources, there is a cost to society that the provider does not pay, and is not reflected in the cost to the consumer of these natural resources. For instance, the Hetch Hetchy Valley would provide a fine recreational facility worth a considerable amount of money to the public if it had not been dammed. Yet the price of water and electricity from the dam is not elevated in order to compensate the public for the lost tourist revenue.

Another very good example of an indirect subsidy is public parking spaces. The amount of money charged for parking is much less than the cost of construction of paved parking spaces and parking garages and the lost real estate, which is often very expensive store front property. Thus people who don't drive fund the driving of those who do.

Hedging

The cost of natural gas or other power plant fuel is captured in the wholesale price of electricity. However, the volatility of such prices is well-known and the provider must take certain measures in order to assure constant service. These measures include purchasing futures or options, price swapping, or storing excessive amounts of resources purchased when the price is low. The costs associated with these actions is passed onto the consumer and represents about half a cent per kWh, or a 10% increase.[21]

Health Impacts

The combustion of fossil fuels results in harmful emissions to varying degrees. The public suffers ill health, medical expenses or even death as a result. These

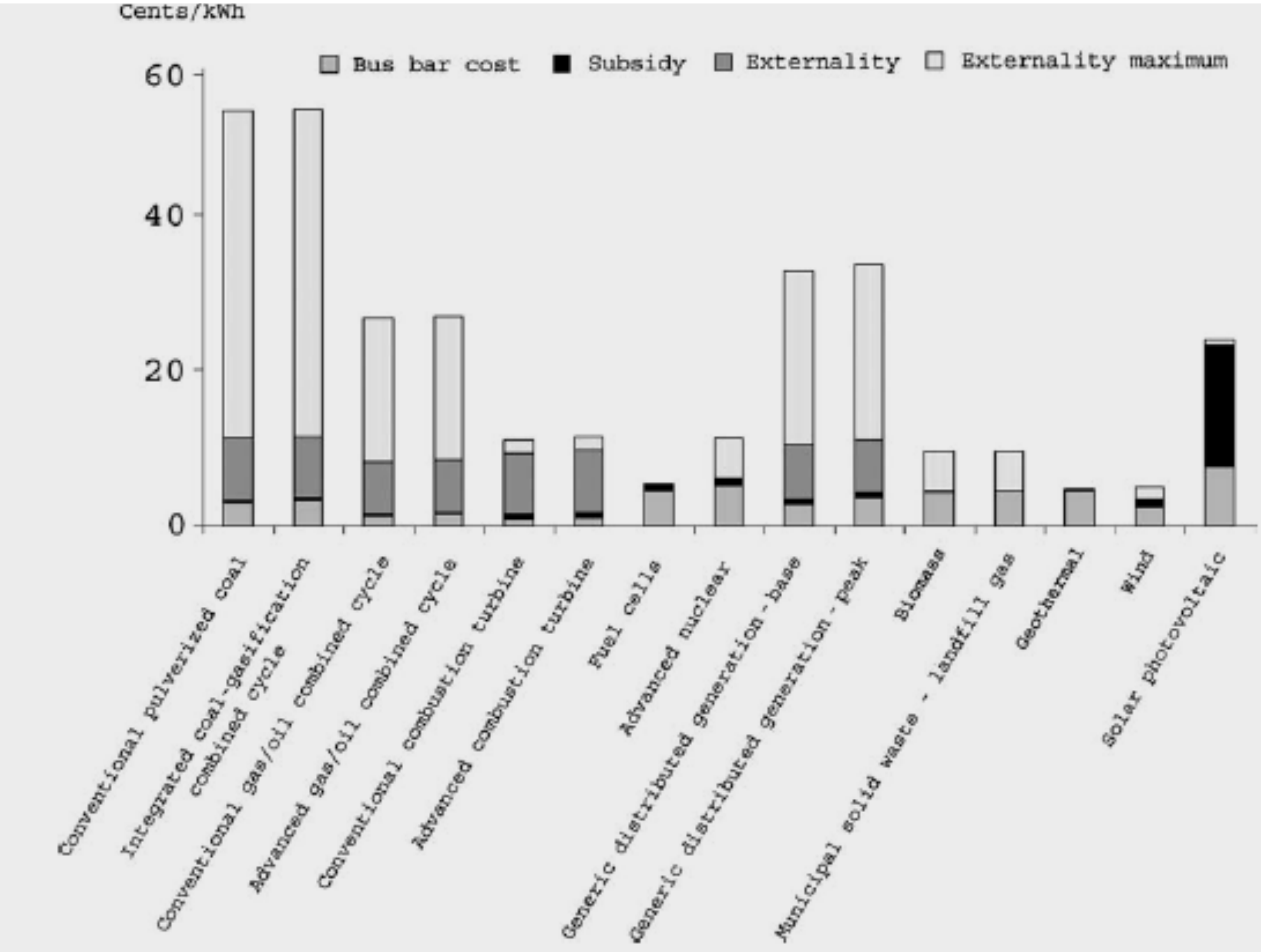


Figure 12 Electricity costs.

costs are not reflected in the cost of the energy. For instance, assessments of 16 coal-fired power plants in the U.S. indicate that the emissions from each are responsible for about 50 deaths and 2000 asthma attacks annually. If one were to assign the value of a life five million dollars, these deaths would correspond to a cost of about $0.50/kWh, or about 10 times the bus bar cost of the electricity produced.[15] If a human life is assigned a value of merely $500,000, the external cost of coal would be 5 cents/kWh, which would still raise the price of coal to be uncompetitive with NG and some forms of renewable electricity generation such as wind. Similar arguments can be made for use of diesel fuel[22] and other conventional energy conversion technologies. The figure above[15] represents an attempt to assemble all production and external costs of a variety of energy conversion technologies.

Impacts of renewable energy on US Energy Expenditures

Several studies indicate that the U.S. can drastically reduce reliance on fossil fuels, reduce greenhouse gas emissions, and reduce other pollutants with an impact to the economy that is either insignificant or *beneficial*. We mentioned above the Stern Report suggesting that the necessary changes to the energy

infrastructure could be achieved with less than a 1% loss of DNP. Two more recent studies conducted by scientists from UC, Berkeley[23,24] reported more optimistic results. The economic modeling project addressed only 8 of a 30 policies identified to reduce GHG emissions. The projected results of these 8 policies were:

- $60 billion increase in gross state product
- Creation of 20,000 new jobs
- 14% reduction in GHG emissions from "business as usual", representing half of the governor's GHG emissions reduction goal.
- The 22 policies yet to be considered are predicted to reduce GHG emissions down to the state's target with positive economic impact.

The positive economic impact is due to several mechanisms:

- Reductions in GHG corresponded to reduced imported fossil fuels. Thus money that would have been sent out of the state (and country) was spent in the state, stimulating the economy.
- Reductions in GHG also correspond to increased efficiency, or less waste.
- Policies will stimulate innovation in energy conversion technology, bringing improvements such as CCHP, and inexpensive wind power.
- Renewable energy conversion is projected to be a monumentally significant industry. Innovations stimulated by these policies will result in California becoming a renewable technology exporter, rather than an importer.

The studies stress that these technological and economic changes will *not* come by themselves, stimulated only by the market place and voluntary actions. Private R&D investment in this area is too little. The government policies considered are very necessary to provoke the change. Appropriate recommendations include:

- A broad, mandatory emissions cap that considers all possible economic activities including production and efficiency actions.
- Allowing the market to respond with free banking, trading, and offsets.

As further incentive to local governments considering Community Choice or municipalization, a recent study funded by US DOE/NREL,[25] which focused on a comparison of the economic development impacts of CSP relative to conventional generating technologies, showed that each 100 MW of CSP results in 94 permanent operations and maintenance jobs compared to 56 and 13 for combined cycle and simple cycle natural gas combustion turbine plants, respectively. Even more impressive, for each 100 MW of installed capacity, the CSP plant was estimated to create about $628 million in impact to gross state output compared to an impact of ~$64 million for the combined cycle plant and ~$47 million for the simple cycle plant. This is mainly due to the higher capital and O&M costs, but also due to the fact that a greater percentage of each CSP

investment dollar is returned to California in economic benefits. For each dollar spent on the installation of CSP plants, there is a total impact (direct plus indirect impacts) of about $1.40 to gross state output for each dollar invested compared to roughly $0.90 to $1.00 for each dollar invested in natural gas fueled generation. These are community benefits that directly offset the cost of any revenue investment and result in a more economically healthy community as well as a community with higher energy quality and reliability.

Conclusion
Significant GHG reductions can take place with minimal negative economic impact, and potential with significant positive long-range impact. These changes will require strong mandatory emissions caps (the push), and economic incentives and education (the pull). The economic costs if we do not act to reduce GHG emissions are significant.

III. Technology Adoption

Quick market penetration of new products is essential for adoption of any new technology, including energy technologies. Santa Barbara's ambitious goals require effective market penetration of renewable energy sources such as distributed solar (including solar thermal, and solar thermal electric, and photovoltaic) and products that use energy more efficiently such as compact fluorescent lights (CFL) and light emitting diodes (LEDs), and alternative fuel vehicles.

The growth of the mobile phone market of European countries from nothing to essentially 100% market penetration in 20 years is a clear indication that market penetration of new technologies can happen fast enough for a complete rebuilding of Santa Barbara's energy infrastructure *if there is a popular driving force.* The rate of adoption of new technologies will be greatly influenced by government actions such as financial incentives, education, and logistical assistance. This will serve to both make the new technology more desirable to consumers as well as overcome consumers' "inertia", or habitual support of conventional energy conversion technologies.

The adoption of renewable energy technology is unique from that of a cell phone in that energy conversion technology acceptance depends greatly on cost. The expected decrease in buss bar cost (cost to produce electricity at the facility) of renewable energy is addressed below. Figure 4 shows how wind energy is the only renewable electricity generation technology that is presently competitive with fossil fuels. However, all electricity generation technologies have exhibited a decrease in prices with increased total production (Fig. 5). This concept is referred to as "the learning curve" or "experience curve". We have seen that the

price of developing technologies decrease by about 20% with a doubling of total capacity manufactured. While the cost of photovoltaics (PV) is presently the most expensive, it also has the least cumulative installed power, and thus should continue to decrease in price (Fig. 6), as will other renewable technologies to a lesser extent. Fossil fuel power conversion on the other hand has already been largely optimized and will thus change little in price, as indicated by the leveling off of the learning curve. In fact, limits of readily available natural gas will doubtlessly increase the price of natural gas fired electricity production in the foreseeable future (Fig. 7). As a last example, NREL forecasts parabolic concentrated solar thermal electric (Fig. 8) will become competitive with NGCC within a decade.

If governments stimulate the renewable markets through incentives and educational programs, the increase in market volume will enhance the progress of these technologies down the experience curve. Interestingly, a decade ago, Neij predicted[26] a decrease of renewable electricity prices and called for government stimulation of the markets, anticipating that wind power (and PV) would become cost competitive with conventional technologies. Since then it is evident that the market prices have marched according to her predictions.

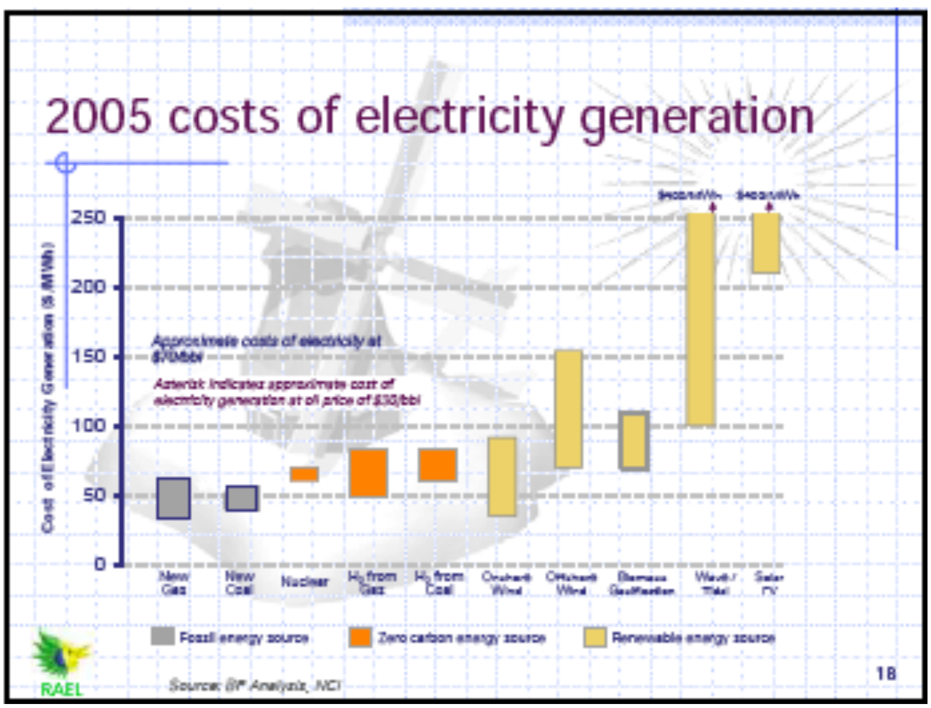


Figure 4, 2005 costs of electricity generation

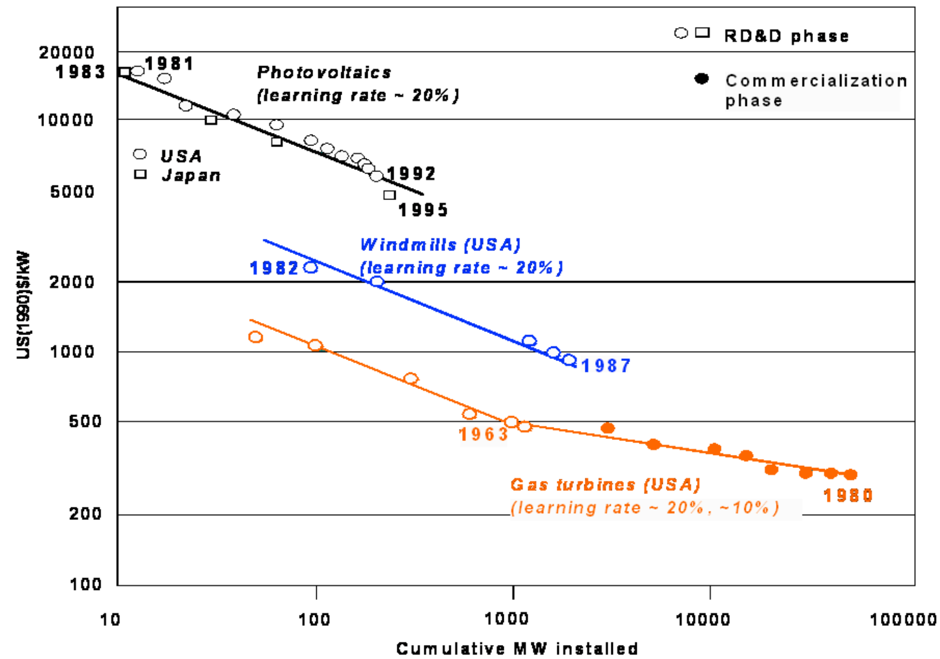


Figure 5, Consistent reduction in costs with increased deployment. Doubling of total production potential results in a 20% decrease in the manufacturing cost of the production facility.[27]

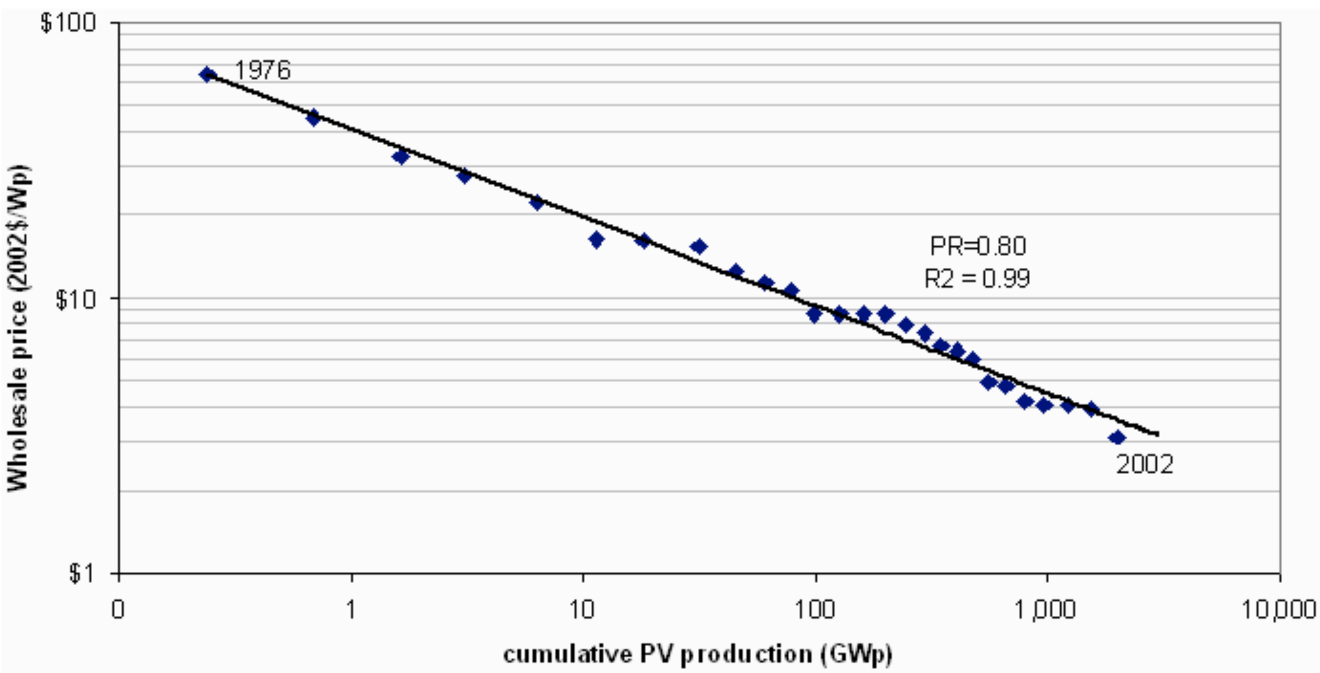
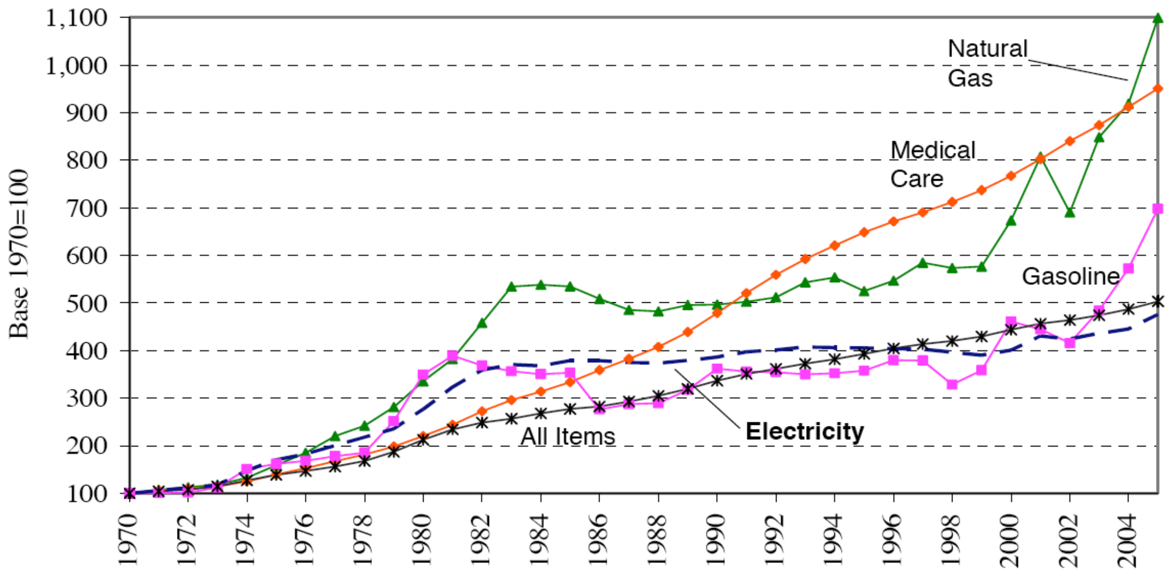


Figure 6, Remarkable reduction in costs of photovoltaic generation capacity. Doubling of total production potential results in a 20% decrease in the manufacturing cost of PV cells.[28]



Sources: EIA Annual Energy Review 2004, EIA Monthly Energy Review March 2006, and U.S. Bureau of Labor Statistics.

Figure 7. Prices of conventional primary energy have increased greater than the average price of "all items".[29]

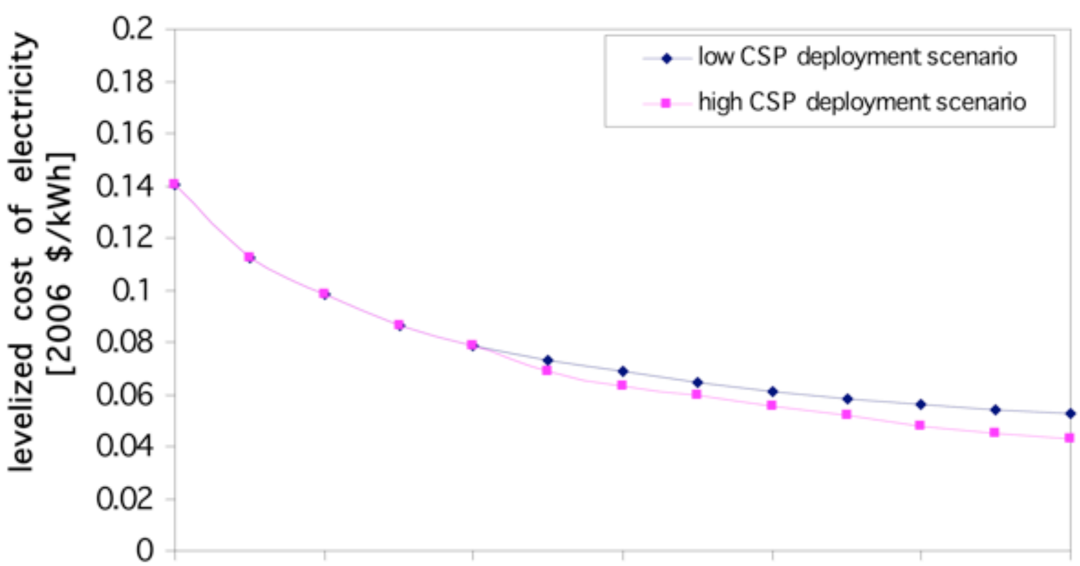


Figure 8 Projected decrease in cost of solar thermal electricity production.[27]

Vehicle Stock Turnover

While replacing inefficient incandescent light bulbs with CFLs and LEDs may take place rapidly with government awareness enhancement, market penetration of alternative fuel vehicles is a significant and important challenge. Transportation fuel represents close to half of Santa Barbara's GHG emissions. Thus any profound reduction in GHG emissions will require significant change in the transportation sector. While it is important to develop non-automobile transportation potential, such as public transportation and bicycle use, introduction of more efficient, and alternative fuel vehicles will also be very important. Santa Barbara has great potential for development of renewable energy sources such as wind and solar electric, which could easily supply all of the present electricity needs as well as replace fossil fuels for transportation. Thus replacement of the present fleet with electric vehicles will be of great benefit.

In contrast to the fairly flat sales of conventional automotive sales, hybrids are experiencing very rapid growth in the U.S. From 2000 through 2006, annual sales of hybrids have grown from 9,000 to over 253,000,[30] an annual rate of increase of almost 70%. It may be reasonable to anticipate significant sales of PHEV (plug in hybrid electric vehicle) within the decade.

New vehicle penetration presents a greater challenge than for electronic technologies because cars are both more expensive and last longer. While government incentives may have a profound effect on which car a buyer may purchase, they will be less effective in swaying the decision of whether or not to discard an old car and buy a new one. The model of our vehicle fleet and turnover is described below.

The California vehicle retirement rate is about 1/15 per year. However, because newer cars are used more often, the effective change in vehicle use happens faster. Figure 9, derived from VISION data, indicates that after 20 years, about 20% of the original vehicles are still registered, but are used only about 25% as often as new vehicles, constituting only about 5% of the miles traveled by vehicles in the first year of ownership.

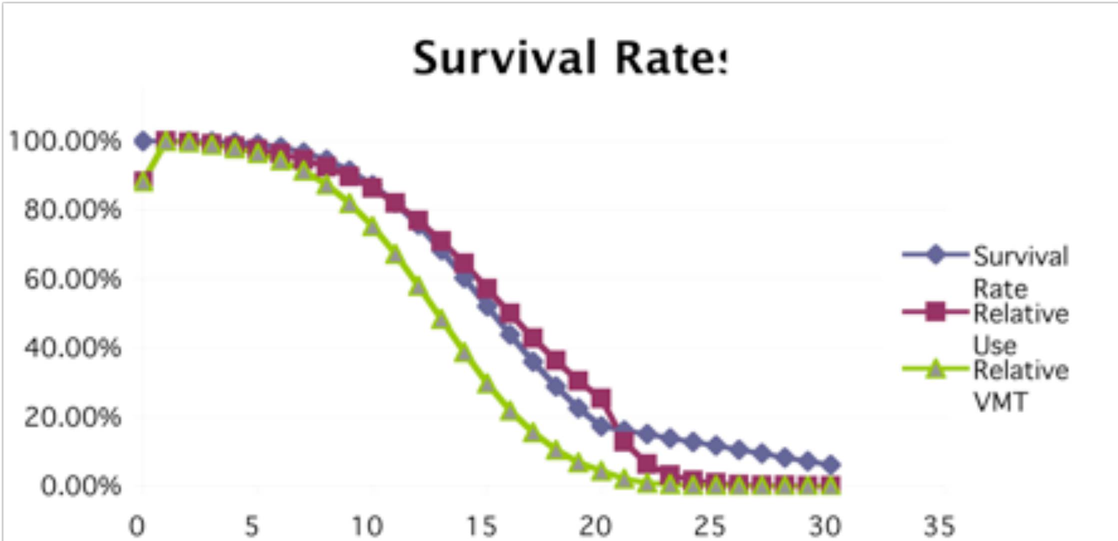


Figure 9 Vehicle survival rate. Vehicle use drops off faster than vehicle registration because new vehicles are used less often than older vehicles. See text.

Using these vehicle retirement data, we are able to estimate the penetration rates of new automobile technologies and increase in average fleet efficiency given projected automobile sales. These data are located on the "Petrol Reduction" spreadsheet. Two examples are given below.

1) Electric Travel Penetration. The potential growth of sales of electric vehicles (both EV and PHEV) was estimated and is shown in Figure 10 (blue diamonds). The portion of the fleet that these vehicles constitute (black squares) lags the sales considerably, but the actual electric travel (red triangles) is somewhat higher because newer vehicles are used more frequently. In order to calculate expected petroleum replacement, our model (Petrol Reduction spreadsheet) assumed that the electric vehicles (some of which are PHEV) only used electricity 50% of the time in the beginning, growing to 90% by 2030 due to improved infrastructure and favorable price of electricity.

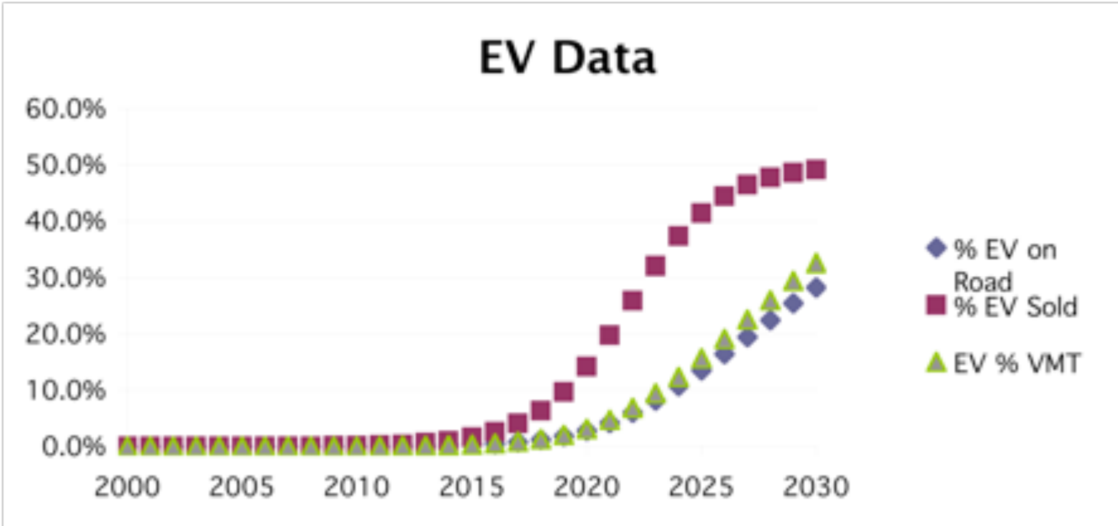


Figure 10, Penetration of electric travel. Because people retain their vehicles for many years, the electric fleet (blue diamonds) lags behind the portion of sales (red squares). Because people use newer cars more often than older cars, electric travel (yellow triangle) rises faster than % of the fleet (blue diamond).[1]

2) Improved mileage. Consistent with recent goals being discussed by lawmakers, we modeled improved vehicle fuel efficiency given an increase in CAFÉ standards by 2030 of from 27 mpg to over 40 mpg (Fig. 11). Again, the actual average mileage *achieved* (red square) lags behind the sales (blue diamonds). The average mileage of the existing fleet is not shown.

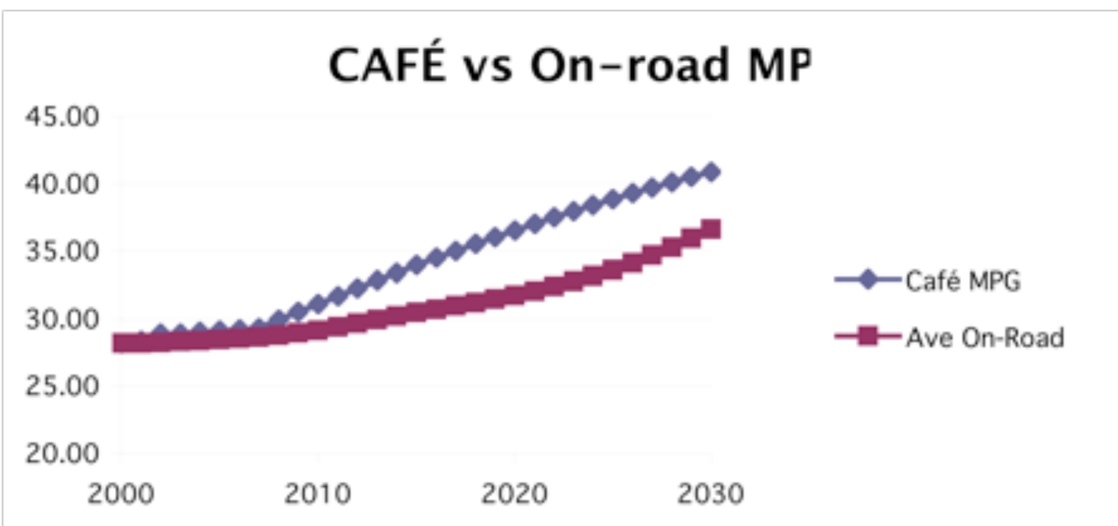


Figure 11, Increased fuel efficiency. Increased mandatory fuel economy (CAFE) of vehicles sold (blue diamonds) requires a significant amount of time to significantly change the average mileage achieved because of the ~15 year automobile lifetime. (see text).

[1] The present VISION model we have does not take this into consideration adequately. However the graph has been corrected and represents realistic projected automobile use.

While the vehicle turnover rate is about 1/15 of the fleet annually for the first few years, some old, poorly-running cars persist on streets. These cars are often inefficient gasoline consumers and also emit significant criteria pollutants. Because many of these cars belong to poor people, the cars are not made to conform to emission standards. There are viable social justice reasons that these cars should not be treated the same as newer cars owned by wealthier people. However, rather than allow these cars to persist on the roads, the car owners and society could both benefit if the government provided funding to assist either the purchase of a replacement car with an "early buyout" program,[6] to repair the car to conform to emission standards.

IV. Distributed Generation (DG), Combined Cooling Heat and Power (CCHP)

This section first explores DG in conventional (fossil fuel) microturbines, and subsequently addresses CCHP to solar energy. It is important to note that microturbines are not carbon neutral unless run on landfill methane or wind turbine hydrogen. For highest carbon reduction, solar (CSP) would provide the heat for CCHP, allowing the possibility for microturbines to supplement need at night.

California's Fossil Fuel CCHP
While our goal is not to increase use of fossil fuels, a study of California's fossil fuel installed CCHP is helpful for two reasons:

1) Fossil Fuel CCHP considerably decreases the amount of CO_2 emissions (and cost) for energy received.
2) A study of Fossil Fuel CCHP will provide important information for CSP CCHP

The heat coproduct from electrical generation (whether from renewable or fossil fuel powered) can be used domestically and industrially to drive refrigeration or heat buildings and water. Between 70% and 80% of the heat rejected after electrical generation can be captured,[15] increasing the effective efficiency accordingly, both in terms of finances and CO_2 emissions (see Fig. 12). Use of heat to drive a chiller is also possible (although the heat-driven compressor is between 5 and 10 times less efficient than an electrical compressor). Additionally, excess heat production would almost always happen during peak power production when electricity rates are highest. A CHP facility may be dedicated to provide heat and electricity exclusively to a specific client, or some of the heat and/or electricity can be *exported* to others (another factory, the grid, a different neighborhood, etc.). A recent CCHP market penetration analysis[31] for 2005 – 2020 considered economic models with market penetration from

2,000 MW[32] (corresponding to the "base case") up to 7,300 MW (resulting from stimulating government policies), or about 20% of California's total electrical supply capability. A cost benefit analysis showed high societal and CHP customer benefits, but high losses to the utility ratepayers and share holders.

In California:

- There is already some active CHP installed in California at 780 sites. Nearly 90% of this capacity is in systems over 20 MW.
- Systems under 20 MW face the challenge of meeting difficult emissions requirements, whether they are reciprocating machines or small turbines.
- With a *total* technical market potential of 14,000 MW, there is a *net* technical market potential of 4,000 MW, and an *export* market potential of 6,000 MW.

Model results:

- The 2,000 MW "base case" over 15 year forecast period saves 400 trillion Btu of energy, close to $1 billion in facility operating costs, and 23 million tons of CO_2 emissions. The high deployment case of 7,300 MW resulted in a five-fold increase in these savings.
- Most California energy users demand a payback time of one year for transition to CCHP. Among "strong prospects", people already actively investigating CHP technology, a 5 year payback period was acceptable.
- An important policy in facilitating market penetration of CCHP was the ability of a provider to export electricity into the grid at wholesale electricity prices, essentially requiring net metering with a required minimum tariff, that allows anyone to be a net producer.

Recommendations

1) Utility-side service incentives, rather than incentive payments with no operational requirements.
2) Implementation of net metering policies mandating a minimum tariff equal to the real time cost of marginal electrical production.
3) Credit for reduced carbon emissions that CHP achieves through higher efficiency (through for instance a production tax credit in $/kWh).

Data for cost calculation of various combined heat and power (CHP) systems (7)

Size	Type	Cost ($/kWh)	Electric efficiency (%)[b]	Thermal output (MMBtu/h)	Overall efficiency (%)[c]
45–75 kW	Recip.	770	31	0.27	80
	MT	800	27.1	0.36	85
75–150 kW	Recip.	730	31.7	0.54	82
	MT	800	27.1	0.73	85
0.75–5 MW	Recip.	600	38	11	85
	Turbine	600	25.5	20	85
5–10 MW	Recip.	550	42	28	87.5
	Turbine	480	31	47	87.5
50–100 MW	Turbine	340	36.5	380	90
	CC	770	49.5	210	90
100+ MW	Turbine	270	36.5	500	90

[a]Abbreviations used include O&M, operation and maintenance; Recip., reciprocating engine; MT, microturbine—less than 750 kW; and CC, combined cycl

[b]Electrical efficiency, overall efficiency, thermal output, and heat rates are based on lower heating value and for CHP operation at full load.

[c]Overall efficiency is based on electrical output (expressed as Btu equivalent) plus useful thermal output, divided by total energy input.

[d]Net heat rate is based on the fuel input minus the fuel required to produce the thermal output using a boiler (assuming a boiler efficiency of 85%), then di by the full load electricity generated by the unit.

Table 4, Data for cost calculation of various CHP systems.[33]

Solar Energy CCHP

Small-scale renewable energy technologies such as STE and PV allow them to be deployed at the point of use. This distributed deployment greatly increases the renewable technologies' economic advantage for two reasons: generated electricity competes with the *retail* cost of conventional power production, and the proximity to consumers facilities residential and industrial exploitation of waste heat (discussed in previous section). It also provides benefits to the utility and society through increased grid stabilization, reduction in reactive and active power line losses, decreased vulnerability to disasters and terrorist attacks and shortages associated with peak electricity use.[34]

Distributed generation (DG) for solar electricity is not universally practical because it requires that the factory or residential area have sufficient solar access. However, one can readily imagine both residential and industrial applications. Possibilities include a dedicated concentrated solar power (CSP) roof facility for a factory such as for the proposed ethanol refinery in Santa Maria, a dedicated neighborhood facility, or even a single home combined heat and power (CHP) CSP installment. Advantages include competing with the higher cost of retail electricity, the ability to use the waste heat, and forgoing the cost of upgrading the grid to accommodate a growing population.

The cost for a utility to produce electricity is approximately 5¢/kWh, 16¢/kWh (peak power production), while the respective *retail* cost is 15¢/kWh, 40¢/kWh (peak power production). CSP and PV are easily scalable to small size and present no environmental reason to be banned from a residential or business area. By generating power at the point of use, the consumer would realize a great savings by paying only the generating costs. The ability to utilize the waste heat (in the case of STE and some PV applications) for heating and air conditioning, domestic hot water, industrial processes, and even cooking displaces the need for natural gas, at the elevated *retail* price of natural gas (about 67% higher than the utility price). Thus the natural gas savings for local electricity generation would be between 5¢ and 15¢ for every kWh of electricity produced. When considering the electricity retail displacement, and use of waste heat, time correlation between peak generation and peak consumption, and externalities described below, one can estimate that for 11¢/kWh that is presently available with CSP, the consumer receives services that if purchased from local utilities would sum to between 17¢/kWh and 58¢/kWh, but most realistically, between 23¢/kWh and 34¢/kWh. This represents an enormous savings, more than 50%. It is reasonable to expect this savings to increase over time, and for solar electricity with potential for local heat and cooling to become competitive as a distributed energy source in the near future.

Recommendations.

A recent study[32] makes the following suggestions to encourage development of DG facilities:

1) Implementation of standard DG connections.
2) Adoption of real time pricing of electricity rates.
3) Implementation of net metering policies mandating a minimum tariff equal to the real time cost of marginal electrical production.
4) Implementation of Demand Response Programs

V. Review of economics of various energy conversion technologies.

Santa Barbara County has abundant potential for renewable energy conversion (Table 5).

Technology	Future potential (GWh/yr)
Biomass Gasification	84[35]

MSW Gasification	77
Geothermal	?
Wind onshore	3,800[36]
Wind offshore	290,000[35]
STE Dish	2,190[37]
STE trough	2,190
STE Tower	2,190
PV, CSP (roof top)	291-6,200[38]
HEPV	
WEC	6,000[39]

Table 5 Santa Barbara Energy Production Potential[40]

Roof Top Solar Electric Potential

We estimate that the 143,000 homes in Santa Barbara have a solar electric potential (STE, PV, or HEPV) of about 700 MW (or nearly twice the average electrical demand in Santa Barbara County). However, this power would be most likely be produced only during the day. It is reasonable to presume that rooftop solar electric production could provide peak power demand with deployment on ¼ of the homes in Santa Barbara County. With appropriate real time net metering that pays all producers for the marginal cost of electricity, consumer-producers would preferentially cover west-facing surfaces in order to produce more electricity in the afternoon when demand is highest.

The above estimation of 6,200 GWh/y roof top solar potential is based on the following assumptions: average daily solar intensity of 250 W/m2 (which corresponds to that of half of Santa Barbara County), a solar conversion efficiency of 20% (between the 10% efficiency one might expect of thin films in the next few years and the 40% efficiency of the new triple junction GaAr PV cells), and every home has 100 m^2 roof top surface area.

Central Station Solar Electric

The area necessary to generate all Santa Barbara County's electricity needs (3500 GWhr/yr) with central station solar electric production is about 8 square kilometers (8 million square meters, about 56 m^2 per home, or 20 m^2 per person. This represents about 0.1% of the surface area of Santa Barbara. This will of course vary with placement and weather, with the most promising sites being northern Santa Barbara County and the Carrizo Plain region of southern San Luis Obispo County.

WEC

Most of the wave energy incident upon California's shoreline originates from storms in the Northern Pacific Ocean. There are two distinctively different wave climates within California, and in fact within Santa Barbara County which are divided at Point Conception (see Fig. 12). South of Point Conception, the coastline is protected from the northern storm swell because of the south facing beach, and the shadowing effect of the Channel Islands. Thus the west facing beaches north of Point conception provide the best resources for wave energy. Additionally, there is great wave energy potential south of Point Conception, but further off shore. However, in order to use this energy commercially, long power transmission cables would be required (roughly 60 miles) to connect offshore wave farms located there to the grid. This has been proven feasible in a number of projects using High Voltage DC Transmission (HVDC) lines, but it would require a fairly large electrical generation scheme to make it economically attractive. It is worth noting that these same off shore sites have tremendous potential for off shore wind power. It is compelling to investigate the possibility of combined wind and wave energy conversion at these sites on a single shared HVDC line.

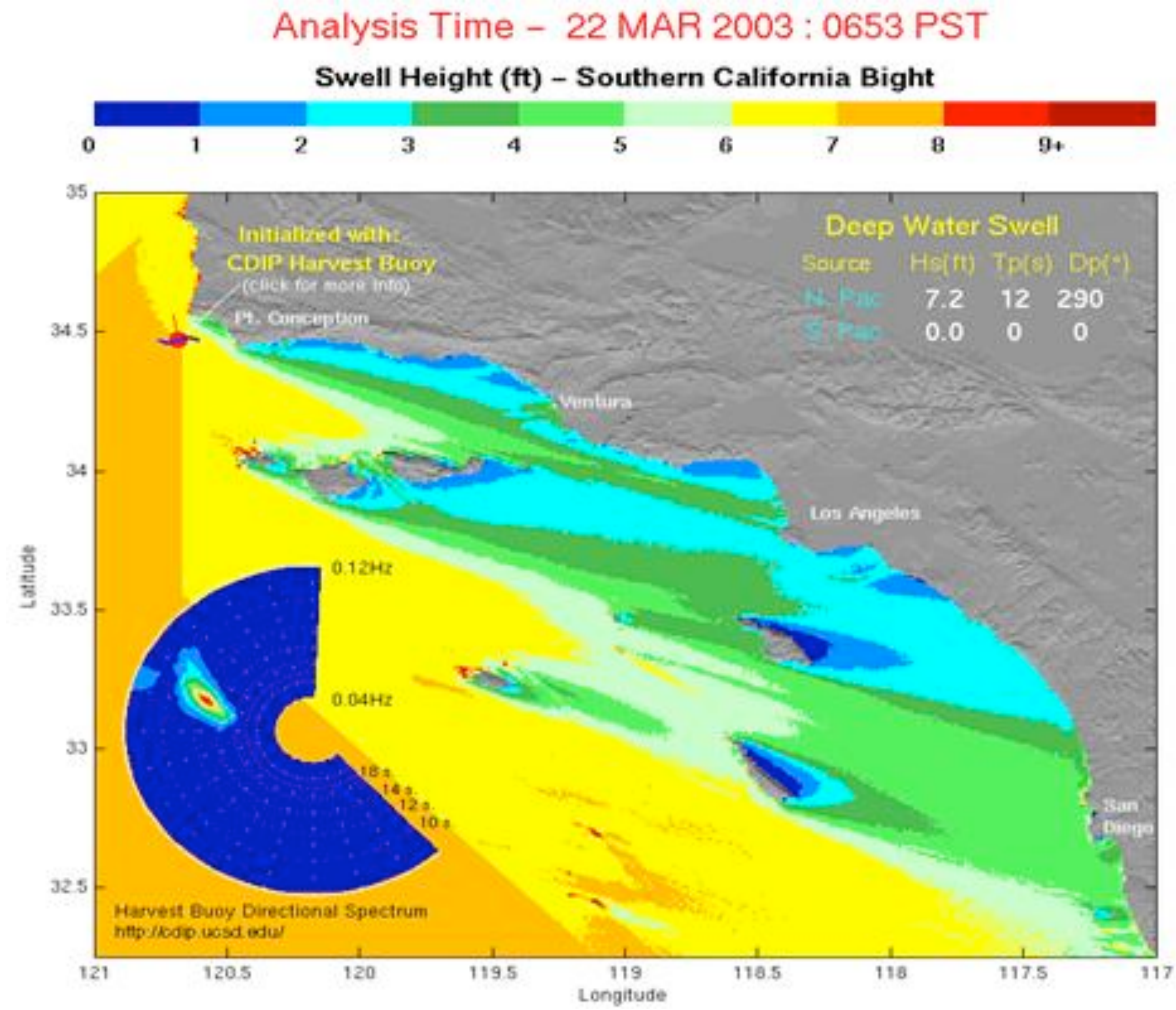


Figure 12. Wave Power Potential for the Santa Barbara Coast.

A recent analysis of wave energy conversion technology[38] reports that wave height is reduced by 12% passing through a Pelamis wave facility, a Pelamis turns absorbed mechanical energy into electrical energy with an 84% efficiency, and average energy density of 25 kW/m in San Francisco. Wave power scales quadratically with amplitude, and a ~16% reduction in wave height exists between Pt. Reyes and Pt. Conception.[41] Santa Barbara has about 130 miles of coastline.[42] We can calculate the following:

1) The power density in Santa Barbara is about 17.6 kW/m.[43]
2) The Pelamis converts wave energy to electrical energy with an efficiency of about 19%
3) The producible power density in Santa Barbara is about 3.3 kW/m
4) The total potential power for Santa Barbara County is about 700 MW.

5) The total potential energy production for Santa Barbara County is 6,000 GWh/y, close to twice the county's total present electrical demand.

Another more direct estimate can be made by observing that the wave energy density near Santa Barbara is roughly equal to that of Hawaii. Each of the 180 Pelamis devices in a facility there are estimated to generate 1.6 GWh/yr for a 9 km facility. A 130 km facility would correspondingly generate 6,760 GWh/y. Another, more recent report[44] has calculated the power density off the coast of Moro Bay to be 24 kW/m. The wave energy off Point Conception should vary negligibly from that of Moro Bay. In this case, one would expect the county's wave energy potential to be 8200 GWh/y.

While it is not practical to harvest all of this power, it is clear that wave energy can provide a significant portion of Santa Barbara's electrical needs.

It may be of use to compare the above map of wave height with the figure 13, a map of presently existing offshore oil platforms,[45] and the wind energy map taken from the wind report (Fig. 14). Circled in red are four oil platforms in water depths ranging from 73 to 205 m, that are strategically located in areas with both abundant wind and wave energy.

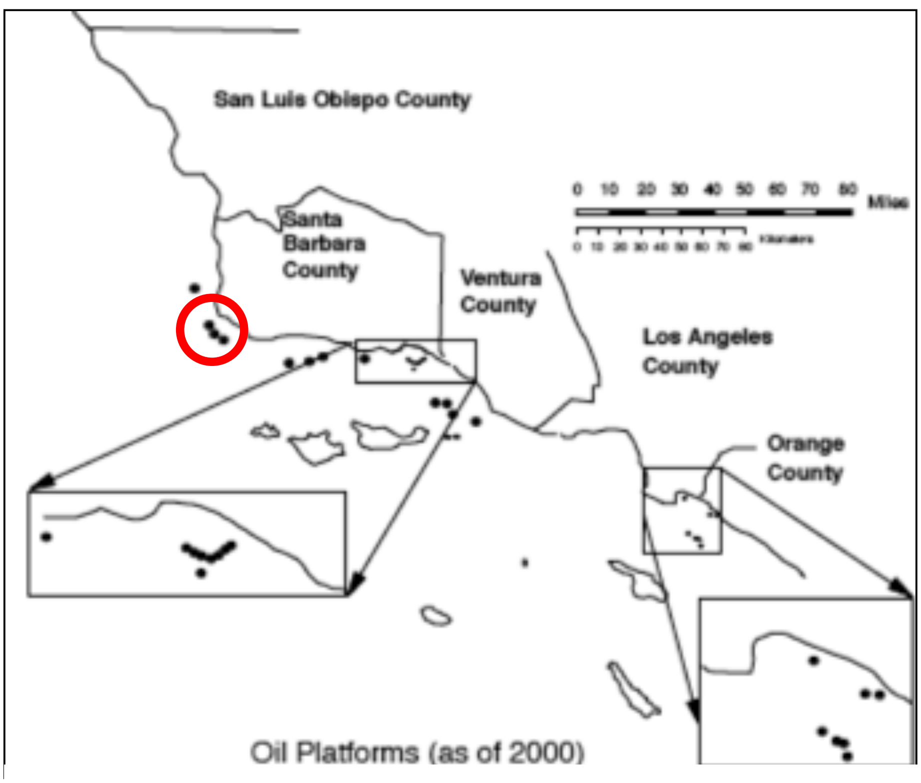


Figure 13. Positions of off shore oil platforms

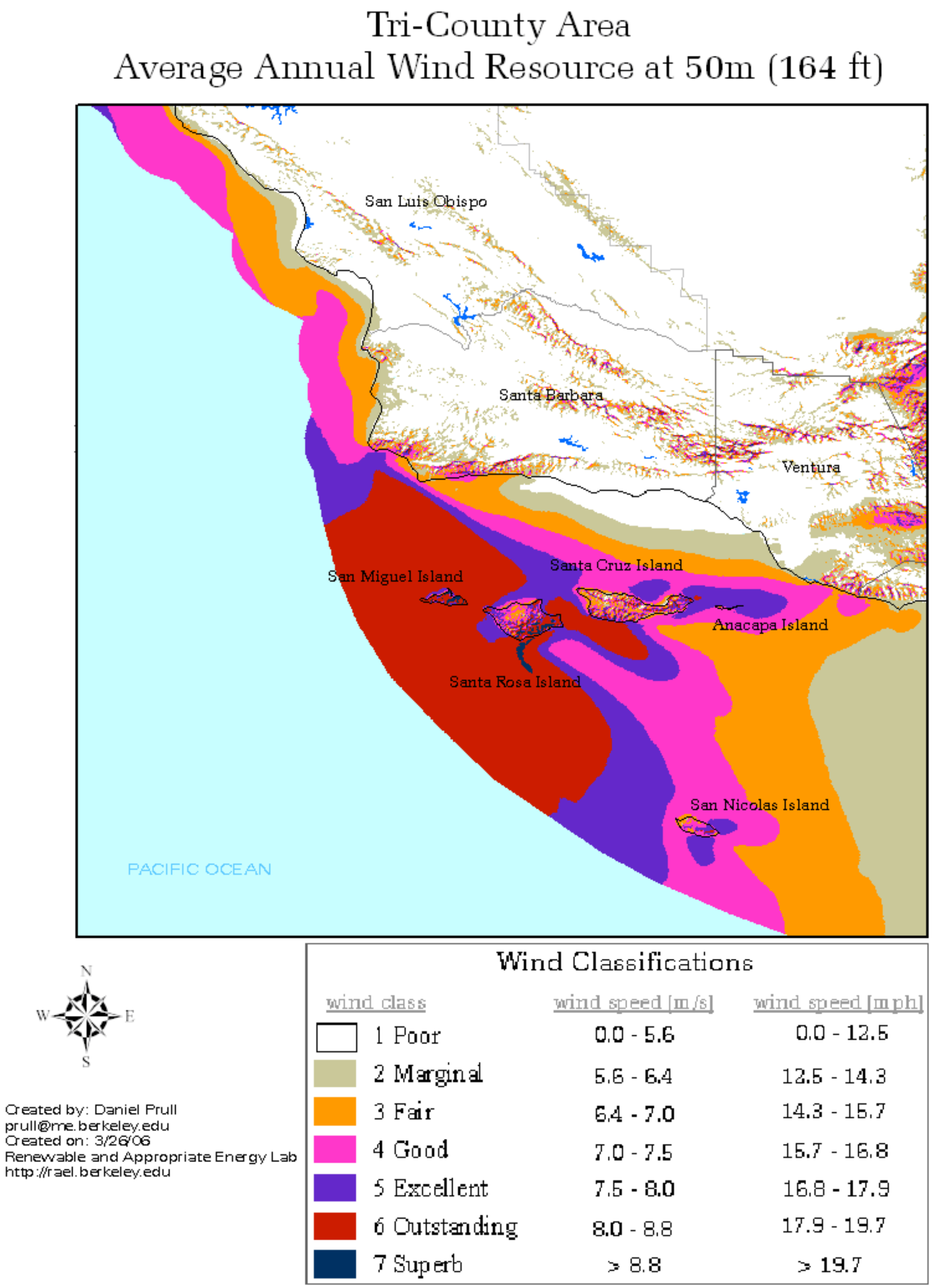


Figure 14. Central Coast Wind Energy Potential

Conclusion
Santa Barbara County has abundant renewable energy sources – much more than necessary to provide energy to the present population indefinitely. Below we explore the costs and challenges of converting to a carbon neutral economy.

VI. Consumer Costs of being "Fossil Free"

Business as usual projections for Santa Barbara County indicate 21.5 TWh/y of energy use for the year 2030. The CEC has provided targets for efficiency improvement and renewable energy generation resulting in zero net emissions of CO_2. This section addresses the cost to consumers of the implementation of these technologies.

The accompanying SBFF33 file balances the energy production and consumption as well as calculates costs. This model is an active, working Excel file that can be modified to explore different scenarios and reflect changes in prices and efficiencies. The "Energy Cost" sheet contains estimates for present and projected energy costs as well as added expenses due to external costs and subsidies. Prices are given as production costs, as well as with external costs and subsidies included.

When external costs are taken into account, wind power is presently the only renewable energy technology that is cheaper than conventional methods. In 2020 most renewable energy conversion technologies will be economically superior to most conventional technologies. However, price per Watt is not the entire story. The variability of renewable energy sources must be mitigated to always meet demand, and every conversion technology meets resistance from some element of society. While these difficulties are significant they must be compared to the staggering environmental cost of *not* switching to renewable energy technologies.

30% PV Tax credit
The marginal federal income tax for families between $74k and $154k is 28%, which is the figure we use. A 30% tax credit amounts to receiving 8.4% of the cost back, or the equivalent of 1.68 – 2.86 cents/kWh on the 20 – 34 cents/kwh cost of PV.

Biomass, MSW conversion technologies
No 2020 price projections are made for MSW and biomass conversion

technologies. Not only would an extensive mathematical model be required, the costs will depend strongly on the growth of the industry during the next 13 years. The following factors will figure into the cost of electricity produced from MSW and biomass conversion:

1. Capital cost – These costs should decrease 20% for every doubling of established production, consistent with standard learning curves.
2. O&M cost – These can also be projected using standard learning curves.
3. Fuel Cost (biomass) - This depends on total demand for biomass feedstock. Demand, and thus cost will most likely increase. Not only will established waste conversion technologies increase biomass demand, it is quite likely that in 15 years time they will compete with cellulosic ethanol for feedstock.
4. Landfill fees - It may not be realistic to use the current historic data because the sudden demand for feedstock may drive down tipping fees, again increasing the effective cost of MSW energy conversion.
5. Market Price Referent - This can be assumed constant over the life of a plant commissioned in the next 5 years. There are no MPRs available for plants to be built in 2020. So when a new plant is built in 2020 they may get a different contract. We can use EIA's projections for prices into 2020 and assume that MPRs also follow a similar time trend.

It is clear that increased deployment will drive down capital and operations costs, but drive up the cost of feed stocks. Without more quantitative analysis, we cannot determine if the combined effect is to raise or lower the cost of producing electricity.

Energy use and Efficiency

The CEC projection for business as usual is shown in Figure 2. 21% of the electricity demand, or 0.567 TWh is presently from renewable energy, and 79% or 2.13 TWh is from nonrenewable sources. Our first step is to subtract consumption due to increased efficiency, a goal of 30% reduction, resulting in a final 2030 demand of 2.33 TWh, of which 1.763 TWh, or 75.7% is unrenewable energy. Additionally, the CEC also postulates a 50% decrease in transportation fuel use by means of increased vehicle efficiency and displacement with alternative fuels, mostly electricity. Our calculated potential reduction is 56%.

Building Energy Efficiency

Building (residential and business) use of energy constitutes 34% of energy consumption. The 2.20 TWh/y reduction in consumption due to 30% increased efficiency amounts to 1.36% per year. Figure 15 indicates that 16% reduction in building energy use could happen at once at considerable *savings* to the consumer. While the *highest* cost (of "residential miscellaneous") is about 4 cents/kWh, the price of the electricity that *wasn't* purchased may vary between

the projected building sector price of 7.4 cents/kWh, to the 15 cents/kWh for residential, to the more than 40 cents/kWh for residential peak electricity consumption. The additional 14% efficiency improvement would cost more as the "low hanging fruit" are taken from the efficiency tree. However, this graph indicates *present* cost to achieve the entire reduction. In the next 26 years, new technologies will emerge that will allow for increased 1.36% increased efficiency per year to be economically advantageous for the consumer. In fact, if the entire 16% increased efficiency were implemented today, the remaining 14% would amount to an annual increased efficiency of 0.58%. The practical matter of implementation has also been addressed in the California energy literature, and is briefly addressed below.

Evaluating a single strategy can make a lower limit of possible increased energy efficiency. For instance, through utility incentives, the utilities pay the consumer for a portion of the cost to implement more efficient technologies, such as LED lights. A recent study[46] of investment by utilities and resulting energy costs indicates a 1% improvement per year for a utility incentive investment of 2.9 cents/kWh, or a total investment (including consumer investment) of 4.35 cents/kWh. Another study[47]indicates that a 1.5% per year reduction (translating a 32.5% reduction between 2007 and 2033) could be achieved if the utility incentives covered the entire implementation costs. A similar analysis of natural gas use yields only a 0.5% decrease in use annually for a cost of 54 cents/therm (about half the price of natural gas). These are the costs of conserved energy (electricity and natural gas) the present study uses. Although the natural gas reduction at 0.5% per annum is only 13% by 2033, these costs are still a reasonable upper limit because the study does not incorporate improved future technologies. Additionally, utility incentives represent only one conservation policy, and one of the most costly. Other, cheaper policies are voluntary increased efficiency, government standards, and Energy Star. Government standards consistent with the "2030 zero energy building challenge"[48] can be enforced on all new buildings, and buildings that are being renovated or sold.

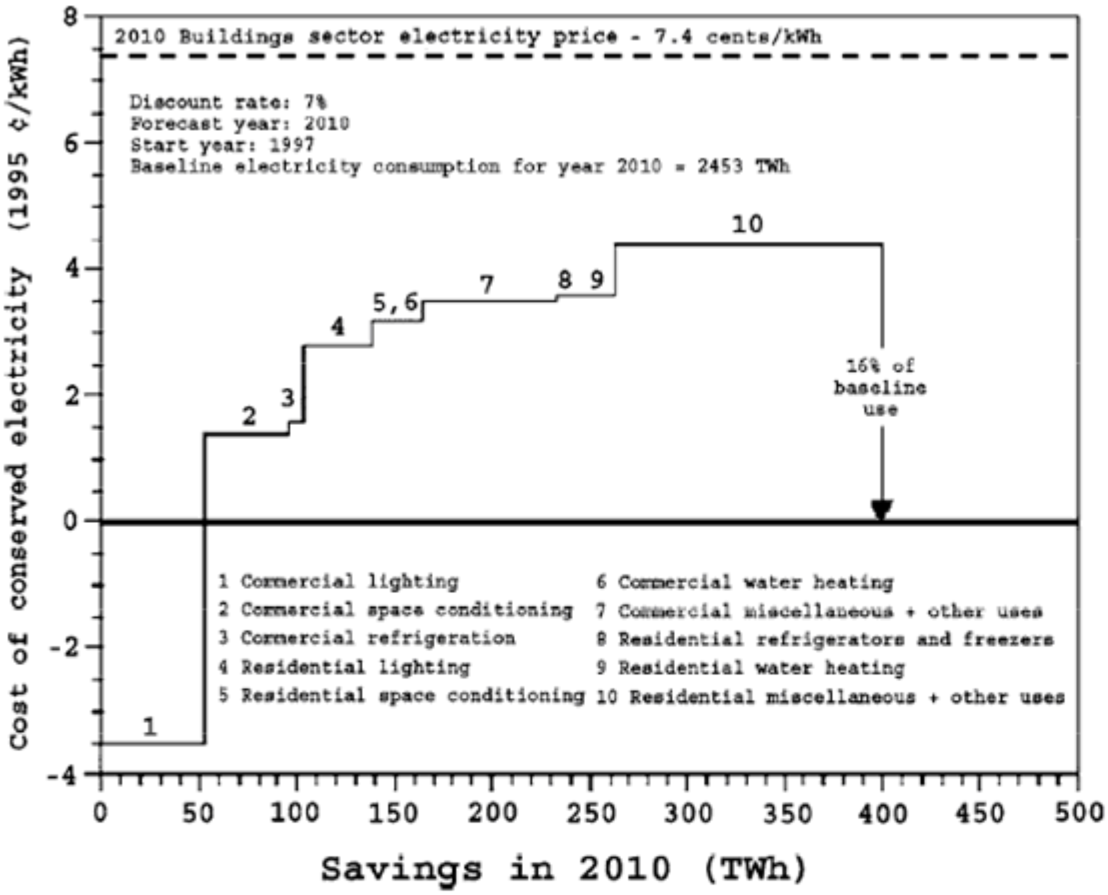


Figure 15, Cost of Conserved Energy[49] [17]

Vehicle Fuel Reduction

By achieving a 50% reduction in fuel use through increased efficiency and alternate energy sources, 5.59 TWh/y of fuel will be saved, or about 26% of the total 2030 Santa Barbara County primary energy consumption. Additional decreases through alternative transportation such as bicycling, public transport, carpooling and telecommuting[50] is not addressed in this analysis. The decrease in fuel use will be achieved through increased vehicle mileage and use of alternative fuels such as electricity and biofuels. The cost of the transition is difficult to assess, and could well be zero or a net savings, as more efficient cars are often smaller, lighter, and less expensive. The California stock turnover rate of about 1/15 per year will allow for most of the cars to be replaced, and the vast majority of the car travel to be with the new, more efficient cars (see chapter I, Technology Adoption, and Fig. 9).

At a consumption rate of about 200 million gallons of gasoline and diesel yearly, and an average price of about \$3.50/gal, the county pays approximately \$700 million yearly for transportation fuel. A reduction in fuel use of 50% would save the county about \$350 million annually, or close to \$1000 per capita. Although the alternative fuels do not come free, electricity for transportation is cheaper than petroleum by about a factor of 10, and may replace the greatest amount of fossil fuel. In order to evaluate the energy and cost balance, we have constructed a simple model located on the "Petrol Reduction" spreadsheet. This spreadsheet is an active working Excel file, as are the other spreadsheets. Thus, the input parameters can be changed to explore different scenarios and reflect technological developments.

Petroleum energy is not displaced by electrical energy 1:1 because electricity is converted to mechanical energy much more efficiently than either gasoline or diesel. While the efficiencies of the internal combustion engines can reach slightly more than 40%, normal driving efficiencies are considerably lower. The efficiency of an electric motor is about 90%. However, there are other considerations that must be taken into account such as transmission line losses grid electricity (about 8%) and upstream energy costs in oil extraction and refining (about 20%). These efficiencies are taken into account in the "Petrol Reduction" spreadsheet, where we estimate that electricity will replace 8 times its energy equivalent in gasoline and 6 times in diesel. We calculate an 11.4% efficiency of an internal combustion engine by comparing two similar cars: the electric Tesla to the ICE Lotus Elise. The Elise has a mileage of about 25 mpg (or about 0.346 km/MJ), where the Tesla consumes 0.110 kWh/km, or 2.53 km/MJ. Assuming a charging efficiency of 0.86,[51] the relative efficiencies of the two engine/transmission systems (electrical/ICE) is about 6.8. The absolute efficiency of the electric motor is about 0.9, yielding an absolute efficiency from tank to wheels for the ICE of (.9)*(.86)/6.8 = 11.38%.

Electric Vehicle Premium

We assign an extra cost for electrical cars due to the cost of batteries. This cost is \$4000 per car for the year 2010, decreasing by \$50 per year to \$3000 by the year 2030. The cost is discussed below and includes consideration of decrease of battery costs over time and increased battery capacity as use of PHEV gives way to full BEV. It is also important to consider that BEV's simpler design (the motor can have one moving part and no cooling or oil requirement) should result in cost savings. Additionally, HEVs and PHEVs require a combustion engine that is smaller than in a conventional vehicle, and therefore cost less to buy and maintain.

A recent report[52] indicates present cost of NiMH battery for HEV to be \$2,500 – \$4,000 for compact and midsized cars respectively, with an immediate projection

of $1,300 – $2,500. An additional $800 - $1,200 is expected for increased capacity necessary for PHEV.

Li ion batteries for PHEV have a projected mass production cost of $3,500 - $4,000 with the present technology. We estimate an additional capital cost of $3000 for electric travel by 2030. This premium could be less, and could also be negative because:

1) Battery technology improvements will decrease production costs in the next 20 years.
2) The decrease in size and capacity of the internal combustion engine (ICE) accompanying the hybrid engine will decrease the cost of engine production.
3) The projected production of electric only vehicles will come with a significant decrease in price with the absence of the ICE.
4) Maintenance costs will be less than for an ICE.

Discussions with battery experts at LBL and consultation with recent news reports from battery companies[53] indicate that increases in battery technology will shortly lead to a battery lifetime that is equal to that of the automobile. Battery recycling technology is also a possibility, additionally decreasing the extra capital cost. We divide the increased battery cost over a 10-year lifetime for today (2010), increasing it to a 15-year lifetime by 2030 – an increase of half a year in lifetime per year of technology improvement. The premium of battery cost is assumed to be $4,000 in 2010, decreasing to $3000 in 2030, or $50 per year. We presume that after a battery dies, a new one is purchased at the current price premium. We estimate this with an annual premium that is initially equal to the total premium divided by the battery lifetime and decreases exponentially with an e^{-1} time of 15 years.

Further Optimization

The scenario chosen for the petroleum reduction does not optimize energy, carbon dioxide, or cost reduction, but rather contains a diverse mix of petroleum for the sake of being comprehensive. For example, the calculation involving hydrogen fuel cells assumes hydrogen production through electrolysis despite the increased efficiency of methane reformation. The reason for this is the potential of nearby abundant wind powered electricity. Greater reduction in GHG emissions would be achieved by producing hydrogen via methane reformation while allowing wind power to displace conventionally produced electricity from the grid. This option would also save more money. Lastly, it would be more efficient and cost effective to do away with fuel cells altogether, using the electricity to directly power six times the number of electric vehicles at much greater savings. Similarly, instead of supplying electricity to produce ethanol, it would be more efficient and cost effective to use the electricity to directly power electric vehicles, doing away with ethanol biofuels.

Biofuels
The CEC projects that biofuels will provide a portion of the transportation fuel consumption. This transition should cost little, as alcohol and biodiesel may well be equal in price to gasoline by 2030. However, this issue is problematic from two standpoints:.

1) Incorporation of biofuels to account for a given amount of transportation energy will not make Santa Barbara closer to "fossil free" by that same amount of energy because a considerable amount of energy must be invested into the production of biofuels. For corn ethanol, the energy investment is mostly in the form of fertilizers and refining.[54] At present, it is reasonable to hope for not more than a biofuel energy return of 30% above what is put in to produce the biofuels. Therefore, the incorporation of 6% biofuels (for instance) into the energy mix would have the effect of using 1.4% renewable energy. We achieve greater reductions in fossil energy by using renewable electricity to supply the input energy for biofuels processing (next point).
2) We must also account for the energy used in the production of biofuels. For instance, in the production of ethanol, our goal is to achieve a (input energy/output energy) ratio of 0.77. We account for this energy with electricity. Doing this is certainly an overestimate of cost because much of the energy actually comes from fossil fuels, which can be converted to electricity with efficiencies less than 60%. However, this puts a lower limit on energy use, and thus backs our final numbers more conservatively.

It is extremely difficult to anticipate future costs and savings in this area, as it depends crucially on the success of cellulosic technologies, government subsidies, and the world petroleum market. It is reasonable to assign a cost of zero to the incorporation of biofuels because the price of biofuels should track that of gasoline.

Wind
The CEC projects that onshore wind will constitute 0.77 and 1.53 TWh in the years 2020 and 2030 respectively, an increase from the present amount of 0.054 TWh. Additionally, offshore wind will provide 2.63 and 3.50 TWh of electricity in 2020 and 2030, respectively. It is important to note that this total of almost 5 TWh of wind energy is well over the projected electrical needs of Santa Barbara County. The electricity should displace all conventional sources (1.76 TWh, at about 5 cents/kWh in 2020 and 6 cents/kWh in 2030) and supply 3.24 TWh of electricity for electric cars, replacing approximately 5 times its energy equivalent in petroleum saving more than 80 cents/kWh.[55] The

(projected Lompoc) onshore wind farm will produce electricity at a subsidized cost of about 3.1 cents/kWh[56] in 2020 and for 3.5 cents/kWh in 2030. The offshore facility will produce electricity at about 6 cents/kWh in 2020 and for 5 cents/kWh in 2030. The savings in nonautomotive electricity production in 2020 would be $13,700,000 and in 2030, $21,300,000. Savings to the consumer will be more because of distribution mark up.

Implementation.
Some of the challenges to implementation of increased efficiency are outlined in the petroleum use reduction CEC special report. Efficiency is achieved largely by making vehicles lighter, with a smaller wind friction coefficient. One of the obstacles to consumer acceptance is the false perception that high vehicle mass is equated with safety. A recent study[57] reveals that while fatal accidents decreased with increased wheelbase, they *increase* with increased vehicle mass. This presents a dual challenge: (1) build the safer vehicle, achieving lower mass with lighter, resilient materials (such as carbon fiber) instead of making the vehicles smaller, and (2) educate the public that lighter vehicles are not less safe.

The model
We use a transparent model on Excel, which takes as input values Santa Barbara's present and projected energy needs, prices, efficiencies, and substitutions. The model calculates new energy production scenarios, the new costs and the savings relative to 2030 BAU. The model is openly available for users to explore other scenarios and different input parameters. The input costs are listed below, as found on the "display" sheet in the Excel model. On the table to the left, the last column represents costs under a carbon tax of $200/Ton of CO_2. Prices used in the model do not assume a carbon tax.

Energy Efficiency			
Cost cons Electricity	4.4	4.4	
Cost cons NG	1.9	1.9	
Technology	2007	2030	2030
Fossil Fuels			Tax
NGCC	9.0	11.3	30.9
NG simple cycle	15.0	18.9	42.1
Coal turbine	4.0	5.0	62.6
gasoline for cars	10.0	12.6	25.8
Natural Gas (Wholesale)	5.5	6.9	16.8
Natural Gas (Retail)	10.4	13.1	23.0
Nuclear	6.5	6.5	

Technology	2007	2030
Renewables		
Hydro	6.0	6.0
Biomass Gasification	8.0	6.0
MSW Gasification	13.0	10.0
Geothermal	6.5	4.5
Wind onshore	5.0	3.0
Wind offshore	7.0	4.0
Wave Energy	10.0	5.0
High efficiency PV	38.0	4.0
STE trough	13.0	4.0
STE Tower	9.5	4.0
Solar Heated Water	4.4	4.4
Roof Top PV	27.0	5.0

Table 6 Costs of Conventional Energy and of Renewable Energy

Price of Renewable Energy

As discussed above, it is widely agreed that conventional fuels will increase in price while renewable energy will decrease in price as the technologies improve. These decreases are based on well-established trends. However conventional energy sources are used to make the renewable energy hardware and therefore renewable energy prices will be (to a degree) linked to the price of fossil fuels. Because conventional fuel prices have been relatively mild up until recently, this effect has not been significant. However, the predicted dramatic increase in price of conventional fuel will most likely increase the price of renewable energy more significantly. Our model allows the user to input an annual percentage increase in the price of renewable energy, above and beyond what is presently predicted.

Offsetting the carbon used.
After efficiency improvements and displacing much natural gas and petroleum use with renewable electricity, Santa Barbara County in 2030 will still consume 1.0 TWh of natural gas, and 3.9 TWh of petroleum (under our aggressive introduction of electric vehicles). We propose to offset this carbon use by exporting renewable (off shore wind) electricity outside of Santa Barbara County, thus lowering the use of fossil fuel used to produce electricity elsewhere. The most conservative estimate is to assume this energy will displace natural gas production via combined cycle. This electricity will displace approximately twice its energy equivalent in natural gas because of the ~50% NGCC conversion efficiency, and about 1.25 its energy equivalent (in natural gas) for petroleum because petroleum has a higher CO_2/energy ratio than does natural gas. The electricity will be produced at the projected cost of (mostly wind) production, and sold at the projected wholesale price of electricity. Mitigation costs are taken into account as well as line losses.

It is important to understand the limitations of the model. A few points are made below. The model can be adjusted with increased analysis and updated data.

1) We estimate that the population of Santa Barbara County will increase from 425,000 to about 500,000 in 2030.
2) For the sake of representing a broad variety of alternative energy sources, our model is not optimized for reduction in either cost or carbon emissions. For example we include hydrogen and ethanol vehicle use although electrical vehicle use would be superior in both categories.
3) The allocation for aviation fuel has not been adequately addressed. Should our estimate of aviation fuel use cover half of the fossil fuel consumed in each in coming and out going flight? Should it include the fact that many people fly out of Santa Barbara first to local international airports and then onto much further destinations?
4) Our calculations include only costs to consumers. The fact that renewable energy requires more money to be spent in building infrastructure locally,

and less to be spent on imported fossil fuels increases the financial advantage of renewable energy.

Conclusions

When all aspects and externalities are taken into account, renewable energy sources have more economic value than fossil fuels for many applications. The results of the model indicate that being fossil free will result in an annual savings of $1.15 billion, or close to $2,300 per person. Renewable energy requires more money to be spent in building infrastructure locally, and less to be spent on imported fossil fuels increases the financial advantage of renewable energy. So the savings to each local person in a fossil free economy may be considerably higher than what is calculated by our model.[58]

As the cost of renewable technologies drops and fossil fuels become less abundant, it also seems obvious that renewable energy will eventually have a cost advantage over fossil fuels for almost all applications. The next two sections address challenges on the road to implementing the environmentally and economically advantageous changes explored in our model.

VII. Public Acceptance (NIMBY)

<u>Particular to Municipal Solid Waste Conversion Technology (MSW CT)</u>
Installing any form of energy conversion technology will encounter local resistance because the project is bound to have a negative impact on at least some aspect of the local domain. This is particularly true for MSW CT because of past experiences with incinerators. It is inefficient to move these projects away from population centers for three reasons:

1) The produced energy is needed in population centers.
2) Combined heat and power is only effective if generated in the proximity of the population center.
3) The fuel source is already located in a population center, and is difficult to move.

An essential step in promoting CT will be to address the concerns of communities and campaign groups opposed to deploying these technologies. The primary concerns voiced by these groups CT are:

1) CT facilities emit toxins (e.g. dioxins, furans, sulfur trioxides, heavy metals).
2) CT facilities reduce the amount of materials available for recycling

3) Conversion of waste to energy should not be considered "renewable."

The current circumstances present a chicken-and-egg problem: emissions data for a commercially-operated CT facility appear to be prerequisites to building such a facility. This leads to one clear policy recommendation: Support the development by the State of California of a commercial scale CT facility to allow rigorous testing and proceed accordingly.

Modern technology and considerate policies can address these three concerns. In particular, when landfill fires are considered, CTs release less pollutants than landfills. However, present perceptions are colored by historical difficulties related to incinerators.

People do not want a plant sited near their home or business. The source of 25% of biomass and largest demand is the city of Santa Barbara. The closest landfill is Tajiguas Landfill. Although it is 23 miles from Santa Barbara City, it is very close to the railroad, which may be helpful.

Wind Power

Large turbines are the most efficient way to produce electricity. However, wind farms encounter public resistance because they change the scenery and cause the deaths of birds and bats. A study conducted in the Netherlands[59] found that about 300,000 birds were killed annually for every gigawatt of installed wind power. This corresponds to about 10^4 kWh/death. Assigning a value of $100 for the life of a bird results in an external cost of 1 cent/kWh. However, it is not clear what value to put on a bird. Additionally, it is not reasonable to assign this cost to wind when one considers the numerous extinctions that will result from global climate change if we continue to consume energy produced via combustion of fossil fuels. Lastly, different sites will have vastly different fatality rates, and the process can be studied and mitigated.

Solar concentrators

Citing issues: Trough technology requires leveling of the land and large use of cooling water[60] (which is abundant for SB only on the coast where there is less than optimal sunlight), or there is a 15% increase in cost of electricity. Near population centers, "waste" heat can be used to heat local water and homes.

VIII. Mitigation of Variability of Renewable Energy.

Do we need to mitigate variability in our region?

As intermittent power sources constitute a larger share of power production, variability becomes more of an issue. At present, little difficulty would result

even if Santa Barbara had 100% variable wind power (for instance), because SBC constitutes only about 1% of California's energy use. The CAISO (California Independent System Operator) would be able to compensate for times of excessive local production or demand, although the grid may need to be upgraded. This may work for a short time, but ultimately supply and demand must be locally balanced if Santa Barbara's energy reform is to be held up as a model to be emulated by other communities. Additionally, the use of variable renewable energy will increase everywhere, so Santa Barbara will not be able to forever depend on the external grid to dependably meet load.

The safest strategy to reliably introduce renewable electricity generation is to keep enough conventional facilities at the ready to power the entire county. However, this comes at substantial financial cost. Below, we also discuss mitigation through a diverse mix of variable energy sources as well as the many power storage technologies of varying costs. Among the strategies to increase the reliability of the supply, we present below the novel solution of *demand side management* (DSM) whereby power *consumption* is adjusted to vary along with the changing supply.

Cost of "firming" wind power and other variable renewable energy sources:
The fluctuations in wind power do not have to be compensated for MW per MW by another power source. Wind power can be treated the same as a variable demand that the system operator must compensate for. Traditionally, the means to control wind power's variability is to have enough power production capacity to do without wind power.[61] Thus the addition of wind increases the use and existence of peaker plants, essentially raising the price of the electricity produced by wind. This increase in expense can be minimized with increased forecasting ability. It is important to note that renewable energy sources have varying degrees of predictability. Wind and solar power can change unpredictably on the scale of minutes, but have average behavior that is somewhat predictable a day in advance where wave energy conversion is very predicable days in advance. Below, we explore more novel ways to mitigate the variability by diversifying the renewable power source inventory, and by modulating the demand (demand response).

DeCarolis and Keith[62] address variability mitigation through geographical dispersion and energy storage. They report the cost of energy storage will increase the price of wind power one or two cents / kWhr, making it still competitive with other carbon neutral energy technologies like nuclear and coal with CCS. They report that an HVDC electricity grid on the order of 1000 miles would substantially decrease wind power variability because it is unlikely that different places will be without wind at the same time. They also found that wind power could become substantially reliable with energy storage capacity sufficient for 10 windless days. However, the model they ran addressed wind

power in the Midwest. The microclimates of the central California coast may afford substantial wind speed diversity over smaller distances, and vary in intensity on shorter time scales than in the Midwest. Another difference is that coastal areas are usually very windy in the afternoon during the summer, largely coinciding with peak demand. Additionally, expanding the energy grid to include other variable renewable energy sources such as solar and dispatchable energy sources such as biomass CT will provide increased grid stabilization. While an extensive wind study has already been completed, the spatial correlation of wind variability and time self correlation have not been addressed. A complete model incorporating these aspects can and should be developed.

The Role of Real Time Pricing and Demand Response:
The simplest and most cost effective solution to the two problems of peak demand and variability, is to have the demand adapt to the availability of the sources. For instance, consumers could charge their plug in hybrid electric cars at night when the demand is very low, or during midday if demand is satisfied by solar electricity. A recent news article in *Nature*[63] discussed how industrial freezers can be programmed to draw power only at night by slightly lowering their working temperature at night and letting the temperature increase during the day. Additionally, in summer, buildings could be slightly precooled at night if electricity is plentiful, and use thermal mass to prevent excessive cooling through the day.

The challenge is to train consumers to adapt their behavior to the availability of electricity. Real time pricing is a "free market" solution, which is strongly advocated by Borenstein,[64] whereby the retail price of electricity corresponds to the price of production at that time. Real time pricing would accomplish several goals:

1) Consumption would adapt to energy variability
2) The "peakiness" of electricity demand would be mitigated
3) The supplier's "monopoly market power" that lead to the California energy crisis of 2001 would be greatly reduced. Under real time pricing consumers would be less likely to use electricity when it was outrageously expensive.
4) Investment in new "peaker" plants would be avoided.
5) Consumer energy use awareness would increase, which would likely lead to increased efficiency.

<u>Transparency:</u>

In order for the demand to adapt to production, the consumer must be constantly aware of the price of electricity. This should become increasingly easy with present improvements with information technology. In fact, energy consuming devices could be programmed to draw on the grid when the rates are advantageous. The energy crisis of 2001 was brought about in part by a completely inelastic demand resulting from the consumer being blind to the cost of electricity.

Community Choice Aggregation (CCA)
If Santa Barbara was a municipal utility, it could be much more creative in the rates they offer customers and the way they integrate renewable energy into the system. Community Choice Aggregation (CCA)[65] is the next best option, by which Santa Barbara can produce and purchase power from outside sources as an aggregate, and sell it to individual parties.

How it could work
Using all production and storage available, a supply curve can be constructed that will passively stabilize the energy market (Fig. 16). Santa Barbara can establish a market by choosing the price to import power or tax power produced by fossil fuels. For instance, wind and solar power may bid in at zero cents per kilowatt-hour (if Santa Barbara is the owner and has already purchased the facilities) and be offered to the consumer for free or a low price. Other power producers would bid at higher prices, and potentially receive a tax if they use fossil fuels or are imported. A stepped supply curve would result (Fig. 16a). The curve is dynamic due to the variability of the energy suppliers, the dashed curve representing a windless day or some other low supply scenario. The system operator may then modify the price curve so that there are no discrete jumps in price (Fig. 16b), allowing a small change in demand to produce a small change in price. Additional steps might be provided by independent short-term production and storage facilities.[66] For instance, when the price of electricity surpasses 15 cents/kWh, several microturbine/CCHP facilities may be programmed to start, and an independent lead acid battery storage facility (that charges up when the rates are low) supplies power to the grid when the price of electricity surpasses 50 cents/kWh. The draw on the grid would determine the price of electricity at that time. The prices listed are the retail price of electricity and are hypothetical values..

It is important to remember that the prices paid to electric power plants in competitive markets are based on the marginal cost of power. A given plant will want to sell power any time the market price is above their cost of generating one more kWh. However, all power plants will be paid the marginal cost determined by the intersection of the supply and demand curve. Renewable energy such as wind can afford to bid in a zero (or very low) because they have no marginal

costs. The large capital costs of building the wind facilities can come from a number of sources including high electricity prices (when demand is high), or as an investment of the community aggregate. The community could also moderate prices to encourage a particular demand behavior. For instance supplying electricity free to electric cars at low demand would encourage several behaviors including electric transport, use of electricity at times of surplus production, and the possibility of limiting the short-term fluctuations through direct control over demand.

Direct Control

The variability of wind power (for instance) exists on three time scales:[57] 4 hour prediction, intra-hour balancing, and the minute to minute regulation. The reliability of the system could be greatly assisted if the system operator could turn demand on and off at will. This is a service that could be provided by consumers in exchange for cheap electricity, such as that provided by public electric car charging facilities controlled by the system operator or by any other industry willing to sacrifice consistency for low price, such as a hydrogen production facility or a battery charging facility.

In Figure 16c, two supply curves are drawn (black) corresponding to high and low supply scenarios. If the consumer always pays 20 cents/kWh (regardless of amount of use) for electricity, the demand would be a vertical line (red) that moves between 200 MW (off peak) and 400 MW (peak). This would have several undesirable outcomes:

1) At high demand and low supply, the price of electricity would go to 60 cents/kWh. In the most extreme case, blackouts would occur, threatening lives, property, and productivity.
2) Considerable presence and use of peaker plants would be required to supply peak demand.
3) At low demand and high supply, readily available electricity would go unused, and could even cause a problem if there was no load on a wind farm (for instance).

However, if the price paid by consumers is proportional to the real time marginal cost of power conversion, demand will be a decreasing function of price, corresponding to the two red curves in Figure 16d. As a result, the price of electricity only varies from 10 – 40 cents/kWh; there will be less of a need for peaker plants, and readily available energy (wind, solar, wave, etc.) will always be utilized.

Implementation

The study of Demand Response (DR) is so quickly growing and changing that little literature is available to the public. Present studies are vast and deserve a dedicated study for Santa Barbara. Important issues include hardware such as the information system to relay the price of electricity to the consumer (cell phone, internet, and radio communication has been suggested). Programmable, communicating thermostats (PCT) can take the price of electricity as an input. Additionally, multiple sensors in a building can customize the temperature and light (for instance) to individuals, and turn to a low energy default in the absences of occupants. Additionally, required inspections (such as air conditioning that, unknown to the owners, may be old and inefficient) and upgrades can be imposed under title 24[7] during building, renovations, time of sale, and can also be encouraged as a matter of course.

It is important to note that the population can adapt over a long period of time as the need grows. At present, the DR required to match supply will amount to a small portion of the uses during a few days of the year. For instance, a number of industrial users might be persuaded to "shed" consumption during peak demand. The extreme consumer adaptation required for a society powered by variable renewable energy indicated by Figure 16d will be required only after the considerable amount of time required to build a renewable energy infrastructure.

Public acceptance of time-varying pricing

The public is often reluctant to accept time-varying pricing. People worry about Grandmother getting a nasty bill surprise for using her air conditioner during the summer. This concern can be addressed by showing that (a) only certain customer classes (e.g., businesses) will have higher power bills, while everyone else's will be lower (if this is true); (b) extra help will be made available to poor grandmothers who can't pay for summer electricity; (c) with adaptation, everyone will win; (d) this is the best way to achieve a goal that everyone wants.

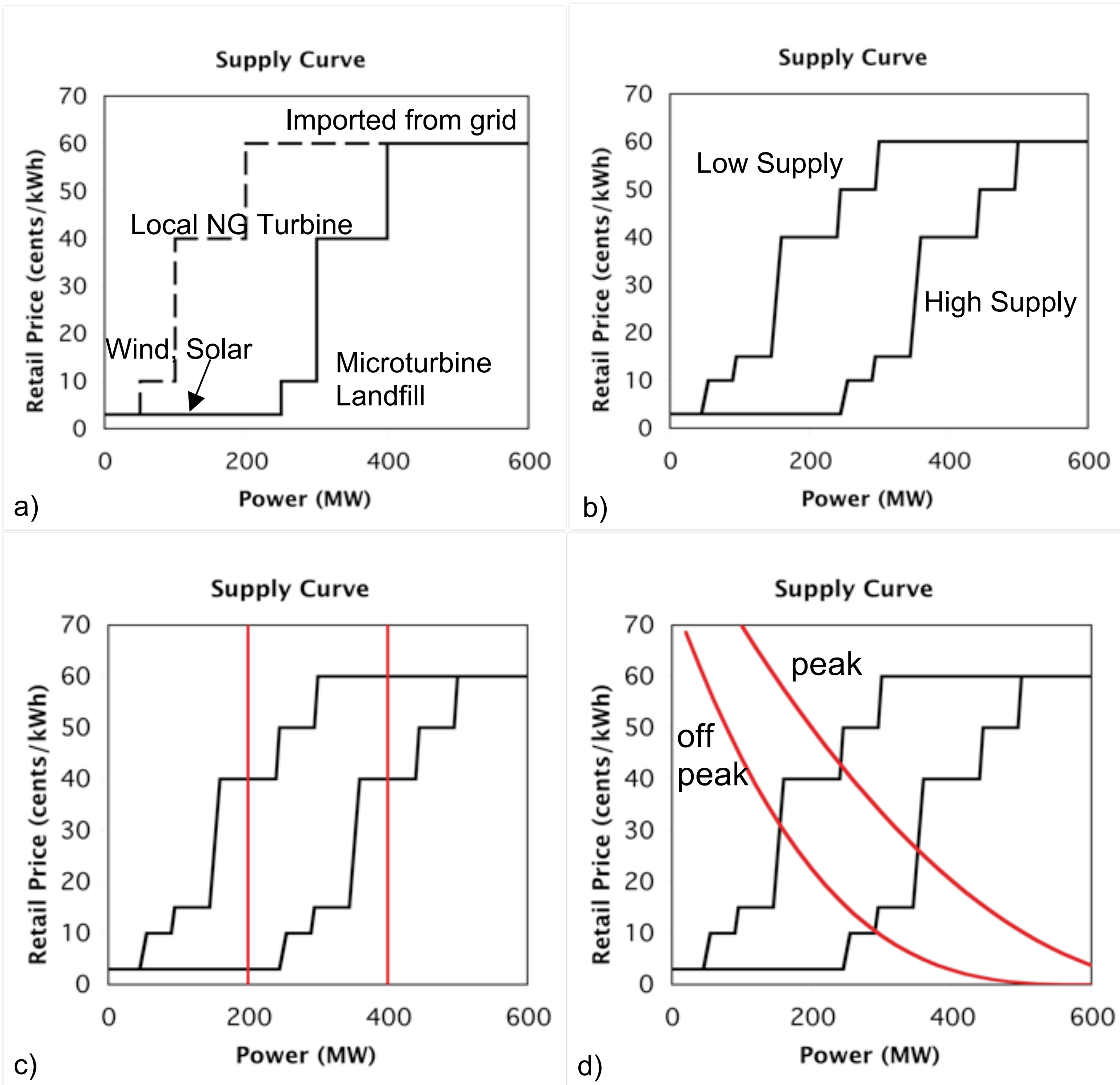


Figure 16. a) A supply curve is constructed from the bids of energy producers. **b)** Due to market forces, energy storage capacity is added from the private sector. **c)** Vertical demand curves resulting from invariant electricity prices, results in volatile production prices. **d)** If consumers are charged according to the price of production, the wholesale market is stabilized.

Recommendations

1) Study the spatial correlation of wind variability in and around Santa Barbara County.

2) Declare Santa Barbara County an aggregate allowing real time pricing on electricity use.
3) Invest in "smart meter" hardware enabling consumers to adapt their behavior to demand and install it in all homes for free.
4) Spend considerable energy forecasting and remedying future problems to the consumer that may stall acceptance of the technology necessary for adoption of renewable energy.[5]
5) Educate the public. There is considerable public reluctance to accept real time pricing due to fear that electricity bills will increase. The fears are unfounded, but very real.[67]

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